GLAST
Mission Operations Center
Design Peer Review

December 15, 2003

Welcome

Dennis Small
GLAST Mission Operations Center Lead

Logistics

- ***Location***
  - *Building 12 , Conference Room E231*
- ***Schedule (one day)***
  - *8:30 am to 3:00 pm – Presentations*
  - *3:00 p.m. to 3:30 – Review Team Summary/Feedback*
- ***Lunch***
  - *We will have up to 60 minutes*

Agenda

8:30 a.m.	*Welcome*	*Dennis Small*
9:00 a.m.	*Mission/Ground System Overview*	*Dennis Small*
9:20 a.m.	*Operations Concept/Scenarios*	*John Nagy*
10:10 a.m.	*BREAK*	
10:20 a.m.	*MOC Requirements*	*JD DeGumbia*
11:00 a.m.	*MOC Design*	*Marilyn Mix*
12:30 p.m.	*LUNCH*	
1:30 p.m.	*Development Approach/Schedule*	*Doug Spiegel*
2:10 p.m.	*Roadmap to GSDR*	*Doug Spiegel*
2:30 p.m.	*Wrap-Up*	*Dennis Small*
3:00 p.m.	*Board Caucus / RFA Review*	*Review Panel*

Review Theme

Purpose of the MOC Peer Review

- *The scope of this Peer Review is similar to a PDR. The MOC design is at PDR-level of maturity. The review describes plans and schedules for managing, implementing and testing the GLAST Mission Operations Center (MOC).*
- *Present the MOC requirements*
- *Provide preliminary insight into plans for achieving operations readiness*
- *Identify open items, issues and external dependencies*
- *To obtain independent feedback and validation of the MOC design and operations plans.*
- *Feedback from this review will be incorporated into the MOC development plans/design and presented at the Detailed Design Peer Review in May '04 & the Ground System Design Review in June '04.*

GLAST MOC DESIGN PEER REVIEW PANEL

- ***Review panel is comprised of experienced ground system development and operations experts***
- ***Pat Crouse***
- ***David Tracewell***
  - ***Representatives from the Code 300 Ground System Review Panel***
- ***Bob Kozon***
- ***Cindi Adams***
- ***Steve Tompkins***
- ***Tim Rykowski***
- ***Dan Mandl***
- ***Steve Coyle***

RFAs

- ***We are accepting RFAs!***
- ***Review panel will document any concerns or actions via Request For Action (RFA) forms***
- ***The RFA will be given to MOC Lead at the conclusion of this review.***
- ***Our responses will be reviewed by the Ground System/Operations Manager, and approved by the RFA generator.***

Road From the GSSR

- ***Ground System received 17 RFA's***
  - *MOC received 3 of the 17 RFA's*
  - *Currently under review by GLAST Systems Team*
- ***Ground System Documentation***
  - *Ground System Requirements Document - (Project CCB)*
  - *Updated Mission Operations Concept Document - (Project CCB)*
  - *Ground System Management Plan - (Project CCB)*
  - *GLAST PSLA Requirements Documents - (Draft)*
  - *MOC Documents*
    - *Statement of Work*
    - *MOC Development Plan - (Draft)*
    - *MOC Functional Requirements Document - (Draft)*
    - Procedure/PROC Style Guide*(Draft)*
    - *MOC Design Specification Document (Draft)*
- ***MOC Procurement***
  - *Project working with Goldbelt Orca/Omitron*
  - *Expect award date January 2004*

Ground System Requirement Review RFA's

RFA Number	Title	Assignee
NO._G001	TDRS Scheduling	Ross Cox
NO._G002	International Agreements	Mike Rackley
NO._G003	GSSC Peer Review	David Band
NO._G004	General Requirement Scrub	Mike Rackley
NO._G005	RF Compatibility	Ross Cox
NO._G006	Risk Triggers	Mike Rackley
NO._G007	Orbit Determination	Mark Woodard
NO._G008	Detailed FDF Requirements	Mark Woodard
NO._G009	Attitude Sensor Calibration Approach	Mark Davis
NO._G010	FDF Launch Criticality	Mark Woodard
NO._G011	Proprietary Issue	Joy Bretthauer /Jerry Edmond
NO._G012	Command Encryption	Mark Melton
NO._G013	Star Catalogue Updates	Mark Davis
NO._G017	"Hot Bench" Usage	Mike Rackley

GSRR RFAs: MOC

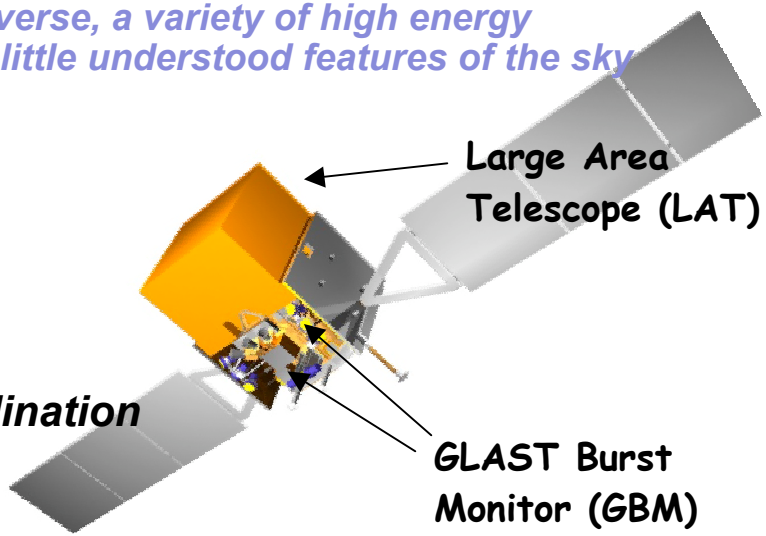
RFA #	Title	Description	Assignee	Status
G_014	Common Discrepancy Database Tool	Determine GSFC requirement for common database for ground system and S/C anomalies	J. Nagy	Response Submitted: Investigated SOAR system, not mature, doesn't provide all required functionality; MOC plans to stay with SERS
G_015	MOC Storage of Frames vs. Packets	Evaluate current requirement for MOC to store packets for the life of the mission versus frames. Consider archiving packets in the MOC rather than frames.	J. Nagy	Response Submitted: MOC plans to archive raw frame files, as received from SN and GN contacts, for life of mission. Raw frame files processed into Level-0 files, which will be transmitted to GSSC, LIOC, and GIOC. The three science centers all plan to archive the Level-0 files. MOC can regenerate Level-0 packet files from frame files at any time.
G_016	Manual Method of ToO Execution	Consider automated method(s) to process ToO requests for off shift periods.	D. Spiegel	Response Submitted: ToO Orders are generated by the GSSC and sent to the MOC for execution. Frequency expected to be approx. once per month. The current plan is for the MOC system to page the on-call FOT for ToO Orders received outside of the normal 8x5 staffed shift. FOT will schedule SN uplink, generate and uplink the ToO commands. Automating the execution of the ToO Order costly, not planned.

Mission & Ground System Overview

Dennis Small

GLAST Mission Summary

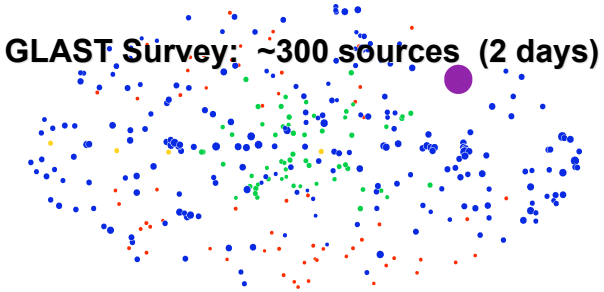
- ***GLAST:*** ***Gamma-Ray Large Area Space Telescope***
- ***Objective:***
  - *Larger field of view (FOV), higher sensitivity, and broader energy detection range than any previously flown gamma-ray mission. Affords scientists the unprecedented opportunity to sample the history of the universe, a variety of high energy astrophysical phenomena, and many of the little understood features of the sky*

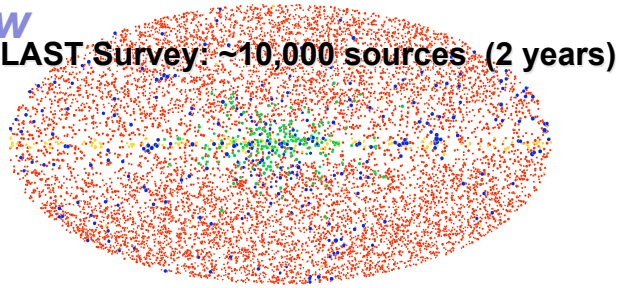


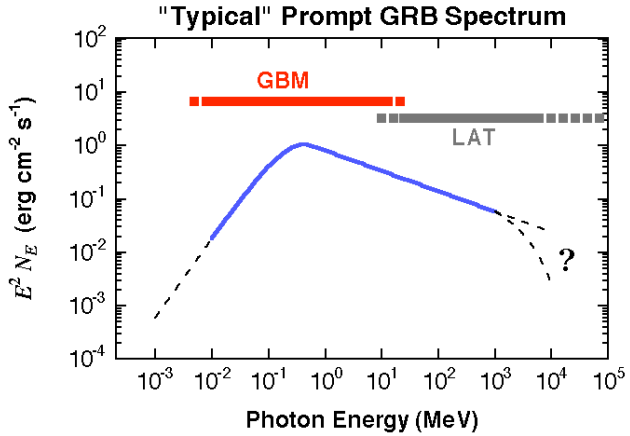
- ***Launch Date:*** ***February 2007***
- ***Mission Duration:*** ***5 yrs (10 yr Goal)***
- ***Minimum Success:*** ***2 years***
- ***Orbit:*** ***565 km Circular, 28.5° Inclination***
- ***Launch Vehicle:*** ***Delta 2920H-10***
- ***Launch Site:*** ***CCAS (Eastern Range (ER))***
- ***TDRSS (SN):*** ***Ku-Band Service (scheduled);***
  S-Band Single Access and Multiple Access (scheduled);
  Demand Access Service (near continuous availability)
- ***GS Sites:*** ***Backup S-band to Wallops, Mila, and USN***

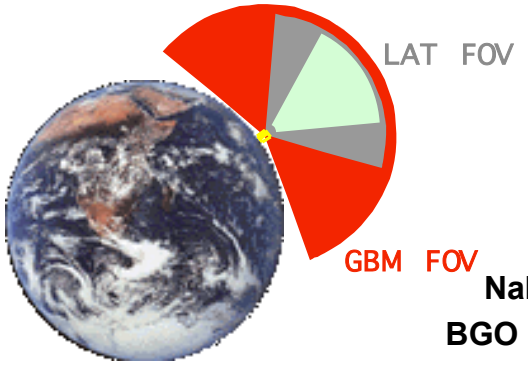
Science Observation Approach

- ***Key Features:***
  - *First year all-sky survey scanning operations*
  - *Pointed observations to any celestial target after first year*
  - *Gamma Ray Burst alert messages with low latency to ground*
  - *Accommodate uploadable Targets of Opportunity (ToOs)*
  - *Autonomous repointing to Gamma Ray Bursts*





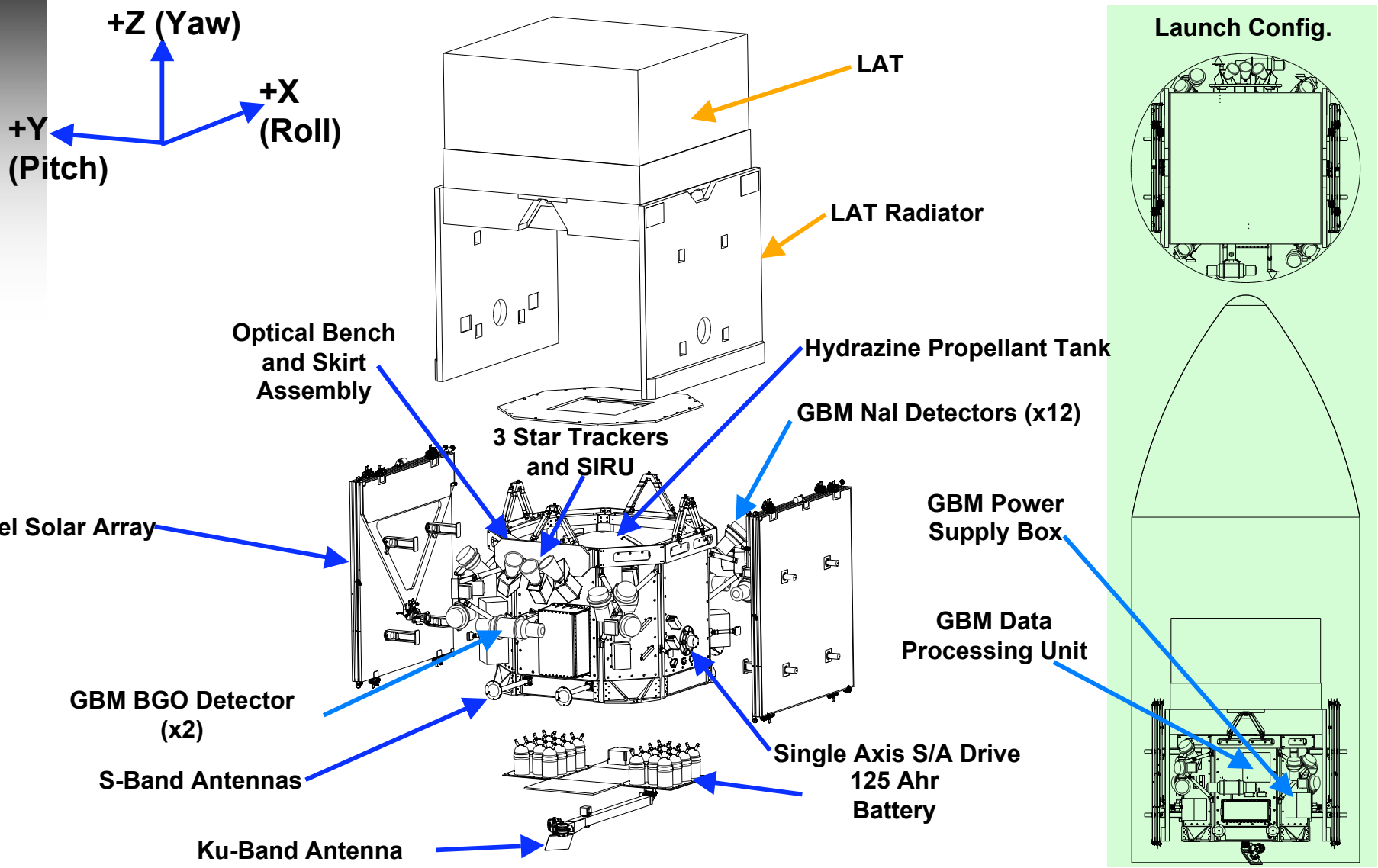




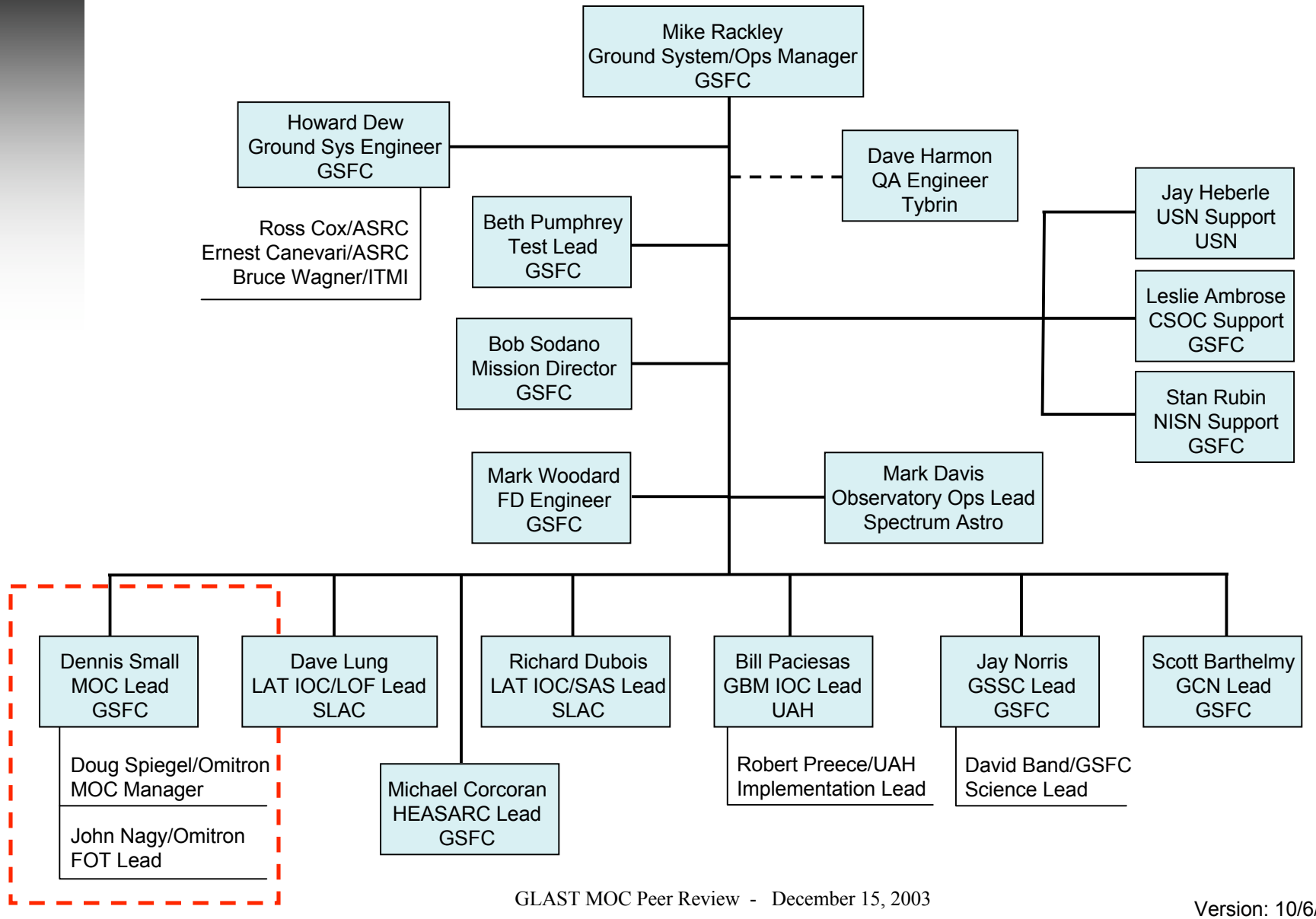
20 MeV – 300 GeV
30° Half Angle – Central FOV
55° Half Angle – FOV

NaI Detector 5 KeV – 1 MeV
BGO Detector 150 KeV – 30 MeV
±120° FOV

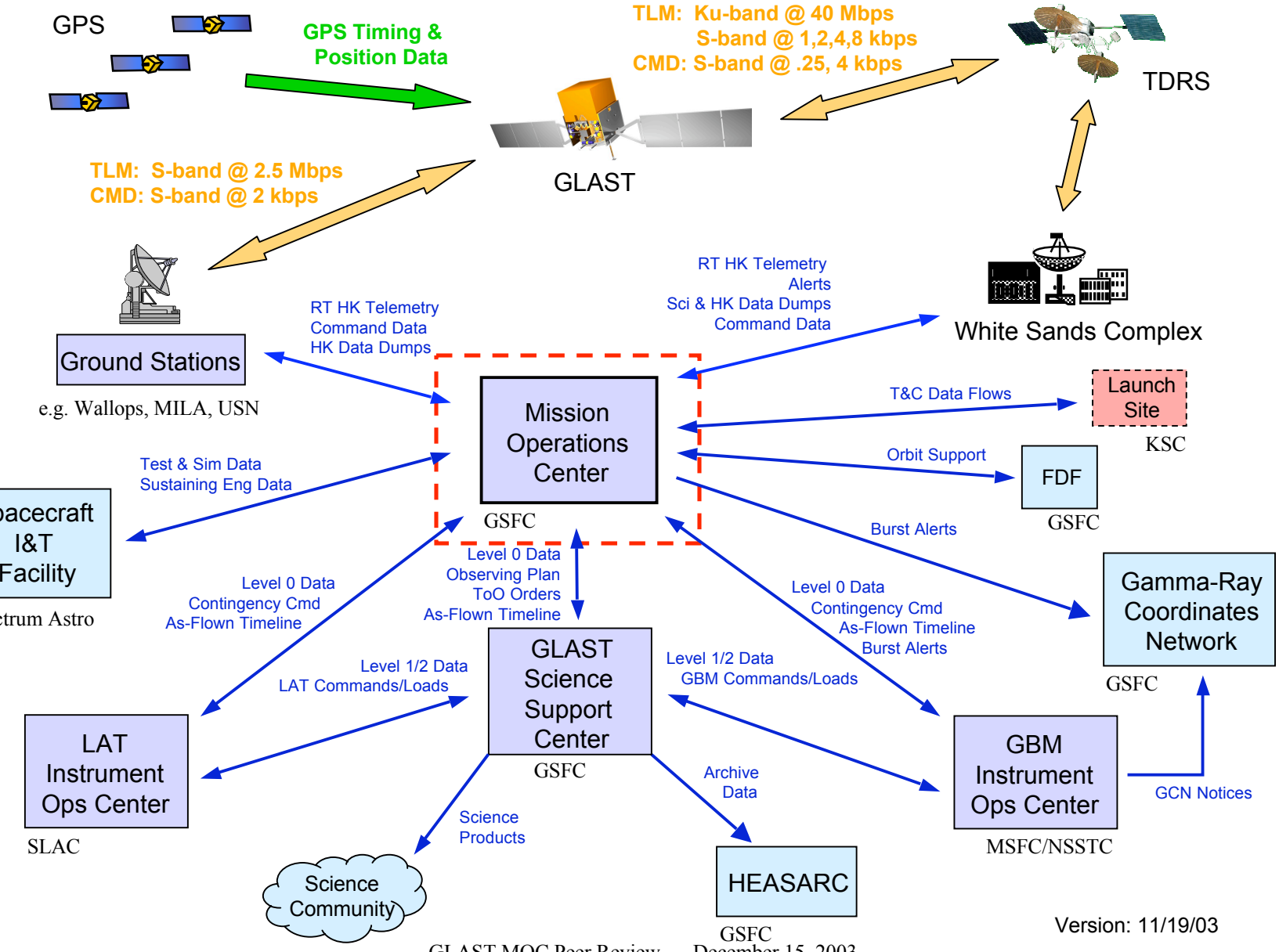
Observatory Layout



Ground System/Ops Organization



Ground System Architecture



Version: 11/19/03

Ground System Architecture

- ***Space Network (TDRS, WSC, DAS, SWSI) – primary communications path for operations***
  - ***Provides continuous MA Demand Access (DAS) service for Burst Alerts and Safe Mode telemetry***
  - ***Provides schedulable MA and SSA service for ToO support, housekeeping, flight software updates***
  - ***Provides 40 Mbps Ku-band return service for the downlink of the science and housekeeping data***
  - ***GLAST provided Ku-band front ends at WSC store and forward recorded frame files***
- ***Ground stations for backup or contingency commanding and S-band Housekeeping data dumps***
  - ***Wallops, MILA (GN); Universal Space Network (Commercial)***
  - ***Perform RS-decoding, report statistics to MOC, sorts data by virtual channel, and time stamps data at the frame level***
    - *2.5 Mbps S-band: Real-time telemetry (HK and Burst Alerts), Memory Dumps, Housekeeping Data Dumps (SSR)*
  - ***S-band data received post-pass within 6 (TBR) hours of end of pass***

Ground System Architecture

- ***Mission Operations Center (MOC)***
  - *Provides real-time command & control, telemetry processing, and data monitoring and analysis*
  - *Provides 24x7 operations support with 8x5 operations staffing*
  - *Provides mission planning, ToO handling, Level 0 data processing*
  - *Serves as single point of commanding for the ground system*
  - *Generates As-Flown Timeline to document what observatory actually accomplished (e.g., reflects autonomous repointing)*
- ***Flight Dynamics Facility (FDF)***
  - *Generates predictive orbit products based on onboard GPS data from MOC and sends to MOC (initial phase)*
  - *Also using Differenced One-Way Doppler (DOWD) from TDRSS, which would go to FDF for use in orbit product generation for initial validation and contingency support*

Ground System Architecture

- ***GLAST Science Support Center (GSSC)***
  - *Supports the Guest Investigator program*
  - *Reviews commands and memory loads from the IOC's for their impact on the observing timeline (science-level constraint checking)*
  - *Provides the MOC with an observing timeline based on accepted Guest Investigator proposals, IOC inputs, and science requirements*
  - *Generates Target of Opportunity orders approved by the Project Scientist and forwards to the MOC*
  - *Ingests data from the MOC (level 0) and IOC's (Level 1/2) for distribution to the science community and mission archives at the HEASARC*
  - *Distributes analysis tools to the science community*
- ***HEASARC***
  - *Provides long-term permanent archive for GLAST*
  - *Receives data products from SSC*

Ground System Architecture

- ***LAT Instrument Operations Center (IOC)***
  - *Performs higher level data processing (Level 1 & 2) using Level 0 data provided by MOC, and provides data products to the GSSC*
  - *Archives and distributes science data products (for LAT collaborations)*
  - *Supports instrument calibration activities*
  - *Performs instrument activity planning, trending & performance analysis and anomaly investigation*
  - *Perform sustaining engineering for the LAT instrument*
- ***GBM IOC***
  - *Performs higher level data processing (Level 1 & 2) using Level 0 data provided by MOC, and provides data products to the GSSC*
  - *Archives and distributes science data products (for GBM collaborations)*
  - *Supports instrument calibration activities*
  - *Performs instrument activity planning, trending & performance analysis and anomaly investigation*
  - *Provides a Burst Alert Processor (BAP) to the MOC that performs additional processing of Burst Alerts to improve burst location information to the GCN*
  - *Perform sustaining engineering for the GBM instrument*

Ground System Architecture

- ***Gamma-Ray Coordinates Network (GCN)***
  - ***Receives Burst Alerts (GCN Notices) from the Burst Alert Processor resident in the MOC and the IOC's***
  - ***For real-time Burst Alerts from BAP, forwards immediately to the science community for rapid follow-up observations***
  - ***Can later receive additional Burst location information from the BAP and IOC's that is forwarded to the science community***
- ***Spacecraft I&T Facility***
  - ***Provides access to spacecraft and instruments during pre-launch testing and operations simulations activities***
  - ***Provides flight software maintenance and general sustaining engineering support (option in Spectrum contract)***
  - ***Hosts copies of the MOC telemetry and command system, and the FOT for preliminary testing of interfaces, telemetry and commands during I&T***
    - *MOC telemetry and command system not required for I&T success*

Mission Operations Concept/Scenarios

John Nagy

Operations Overview

- ***MOC/FOT provides "front-line" support for spacecraft and instrument health and safety and performance monitoring/trending***
- ***All commanding done from the MOC telemetry and command system***
- ***Space Network (TDRS, WSC, DAS, SWSI) – primary communications path for operations***
- ***Ground stations for backup or contingency commanding and S-band Housekeeping data dumps***
  - ***Wallops, Mila, and Universal Space Network***

Operations Overview

- ***LAT and GBM detect Gamma-Ray Bursts and generate Burst Alerts that are sent to the ground via the continuously available SN/TDRSS Demand Access Service (DAS)***
- ***Orbit determination highly automated due to use of on-board GPS***
- ***MOC support of additional orbit determination methods to augment the on-board GPS capability***
  - ***Used to help verify the GPS capability during L&EO and for contingencies if GPS capability is ever unavailable***
    - *Differenced One-Way Doppler (DOWD) with TDRSS*
    - *NORAD-generated Two-Line Elements (TLE's)*
- ***Majority of science and mission operations are pre-planned and executed from stored command loads***

Operations Overview: Observing Modes

- ***Survey mode - primary mode of operation for the 1st year All Sky Survey***
  - ***Rocking survey (up to ± 60 degrees)***
  - ***General Zenith pointed survey***
- ***Pointed Observations***
  - ***Inertially pointed at specific targets***
  - ***Pointed observations are planned via the weekly science timeline***
  - ***Target of Opportunity (ToO)***
    - *Project Scientist able to quickly retarget observatory via Target of Opportunity (ToO) Requests*
    - *Turnaround requirement < 6 hours (4 hours for the MOC)*
    - *ToO requests are not intended to replace late schedule changes*
    - *ToO requests are not included in the weekly science timeline*
  - ***Autonomous Repoint (AR)***
    - *Onboard target request which will repoint the LAT to a detected burst*
    - *Settable duration by ground command (default will be 5 hours)*
    - *Upon completion of the AR the stored timeline will resume at the appropriate target*

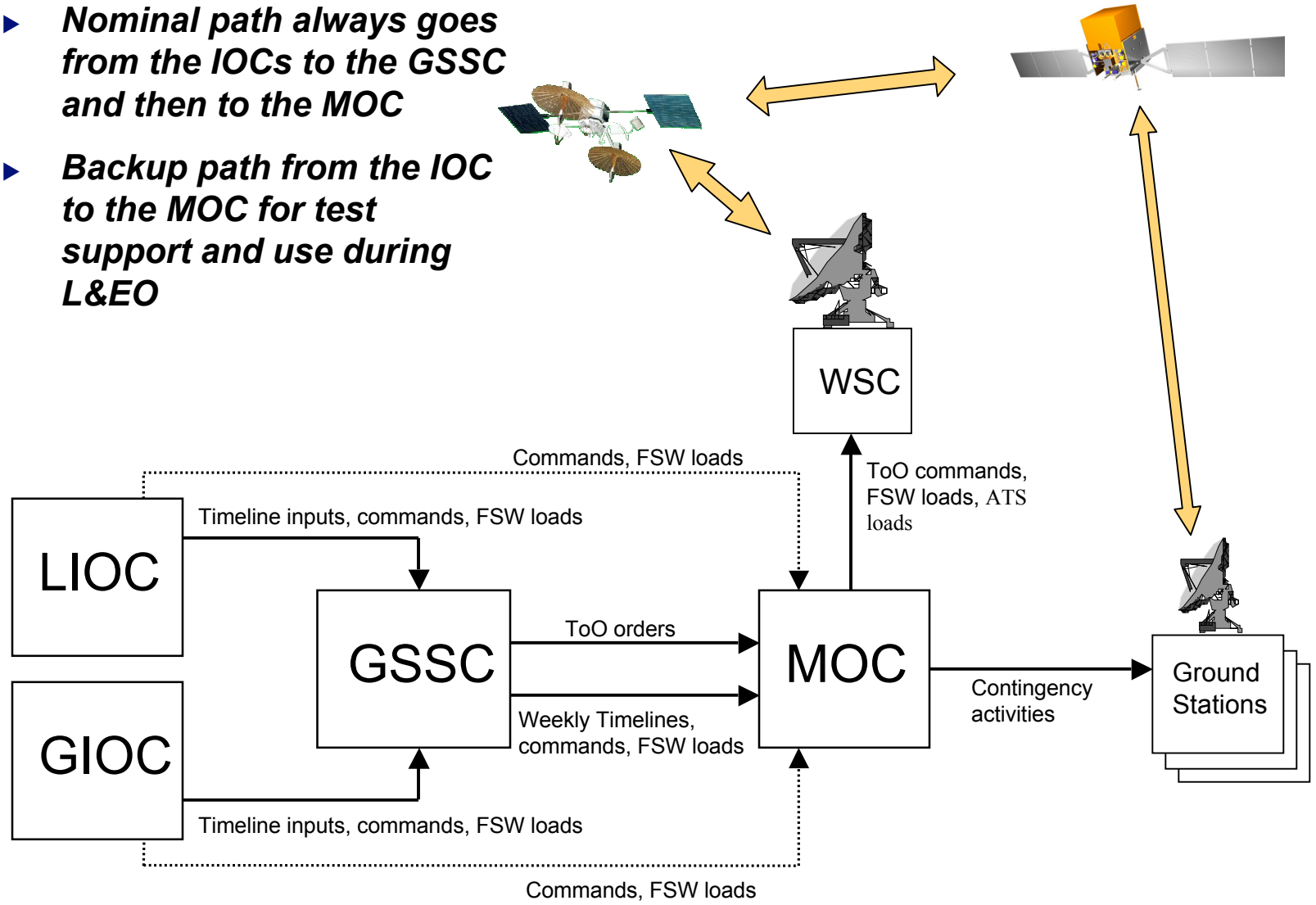
Operations Overview: Week in the Life

- ***Nominal MOC Operations Highly Automated (approach based on Swift, IMAGE, MAP, SMEX, etc. heritage)***
  - ***Single 8x5 Staffed Shift (On-call FOT outside normal 8x5 shift)***
  - ***4-5 scheduled passes per day with TDRSS Ku-band service***
  - ***Manual Activities (FOT)***
    - *Mission Activity Planning and Scheduling, SN and GN (as backup) Scheduling, Real-Time commanding, Telemetry Monitoring, Spacecraft and Instrument FSW Loading, MOC Maintenance (PDB, Software, or Hardware)*
  - ***Automated Activities (Software, Scripts)***
    - *Off-Shift Pass execution, Data Processing, Telemetry Monitoring, Data Archiving, Trending, Event Logging, Alarm Recognition, Automated Personnel Notification*

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8AM	- R/T command opportunity	- R/T command opportunity - Mission Planning and Scheduling	- R/T command opportunity - Uplink new ATS	- R/T command opportunity	- R/T command opportunity	***On-Call***	
5PM	- L0 processing - Data trending	- L0 processing - Data trending	- L0 processing - Data trending	- L0 processing - Data trending	- L0 processing - Data trending	- L0 processing - Data trending	

Mission Planning and Command Generation

- ***Nominal path always goes from the IOCs to the GSSC and then to the MOC***
- ***Backup path from the IOC to the MOC for test support and use during L&EO***



Mission Planning and Command Generation

- ***GSSC serves as central collection point and coordinator for science/mission planning and scheduling, providing an integrated science timeline to MOC weekly***
  - ***Integrated science timeline is a list of activities and/or commands for the instruments and observatory***
  - ***Timeline inputs are received from the IOCs***
    - *FSW loads, calibration activities, instrument adjustments, etc.*
  - ***GSSC checks for impact to existing timelines and notifies IOC if there are problems***
  - ***Nominally covers a period of at least 7 days received 2 days in advance***

Mission Planning and Command Generation

- ***MOC merges the integrated science timeline received from GSSC with spacecraft commands such as TDRSS contact schedule, SSR control commands, ephemeris updates, etc.***
  - ***MOC receives timelines from GSSC and MOC checks***
    - *Constraint checking, invalid commands or missing sub-mnemonics, out of range parameters, command frequency limit violations, etc.*
  - ***Absolute Time Sequence (ATS) load created and uplinked to non-active ATS buffer for later execution***
  - ***ATS contents are absolute time tagged commands such as instrument commands, transmitter on/off sequences, recorder playback/stop commands,***
- ***GSSC also forwards instrument FSW tables provided by the IOCs to the MOC for uplink***
  - ***Uplinked as per instructions given with each table/load***

Space Network Scheduling

- ***Ku-band antenna TDRSS contacts are contingent upon spacecraft attitude.***
  - ***MOC extracts attitude information from the weekly science timeline***
    - *extrapolates the survey time into predicted attitude information*
  - ***Create a week long predicted attitude file modeling the s/c motion during the science plan***
  - ***MOC tool reads predicted attitude file for the entire week***
    - *predicts all GLAST to TDRSS views using antenna mask, predicted orbit ephemeris, and TDRSS ephemeredes*
  - ***MOC scheduling tool filters the week long file and attempts to choose the best passes based on preset criteria i.e. pass length, length between passes, number of minutes per day of downlink, etc.***
  - ***MOC analysts review the filtered schedule for completeness and schedules the 4 to 5 passes per day with SWSI***

Space Network Contact Profile

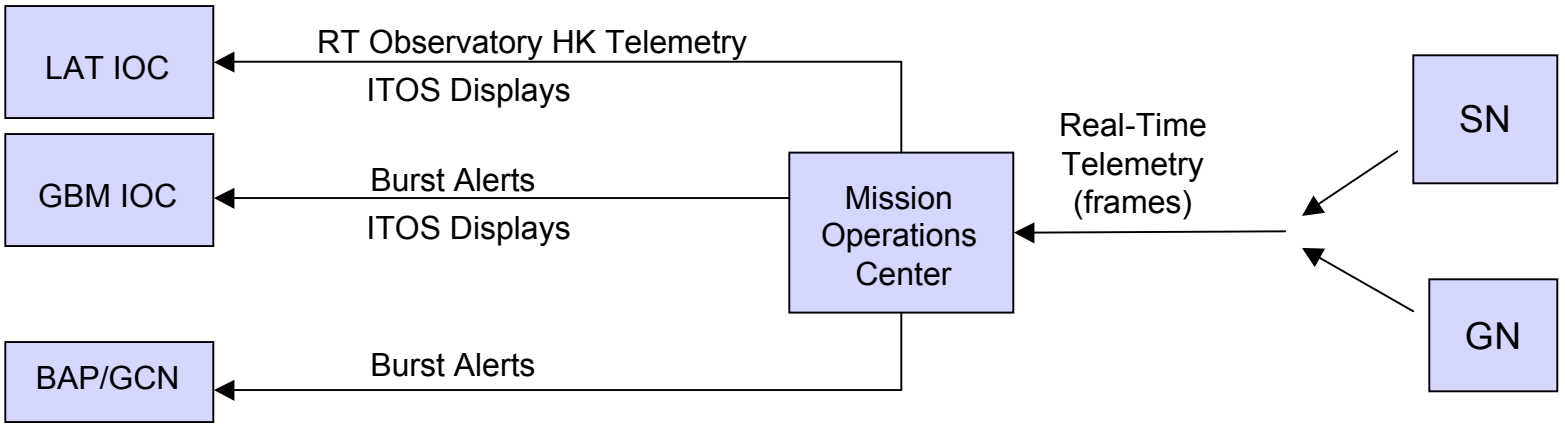
- ***Ku-band antenna configuration and spacecraft attitude limit TDRS contact to 5-7 minutes per contact***
  - ***Relatively large number of short duration contacts available per day (current best estimate is more than 75 opportunities per day)***
- ***GSRD Requirement mandates that science data gathering will not be interrupted for SSR dumps***
- ***Autonomous Repoints (AR) are expected to occur about 1/week and last 5 hours. These will have a high probability of impacting a previously scheduled pass.***
  - ***Extra "contingency" downlink minutes will be routinely scheduled to compensate for any missed passes, should they occur.***
  - ***FOT must asses the impact of AR and reschedule as needed***
  - ***96 Gbit SSR size provides ~65 hours of onboard storage for science and housekeeping***
    - *low probability that data will be lost due to a missed pass*

Changes to a scheduled science plan

- ***Interruptions or changes to the integrated science timeline***
  - ***New integrated science timeline received from GSSC***
    - *Previously scheduled TDRSS views will need to be evaluated for any impacts. Changes solely in instrument modes (not effecting pointing attitudes) will not necessitate replanning.*
  - ***Target of Opportunity (ToO) requests from the GSSC***
    - *Previously scheduled TDRSS views will need to be evaluated for any impacts.*
  - ***Autonomous Repoint requests (ARs) from the LAT instrument***
    - *May cause the interruption of TDRSS contact(s) during the duration of the autonomous repoint.*
  - ***FSW will return to previous observation mode where it would have been prior to the AR or ToO. In essence the GN&C preserves the originally scheduled attitude profile.***
    - *The ground software only has to model the survey mode for the week and ARs/ToOs should not cause a cascading interruption.*

Real-Time Telemetry

- ***Ku-band Front-end at WSC forwards selected Virtual Channels (VC's) to MOC in real-time (frame data)***
  - *Observatory HK telemetry, Burst Alerts, Safe-mode telemetry, and Memory Dumps*
  - *All VC's stored at station and forwarded to MOC post-contact*
- ***MOC performs traditional real-time processing on incoming telemetry***
  - *Extract packets, decommutate and display HK data, generate/display event messages and alarms, perform command verification*
- ***MOC will forward instrument packets in real-time to the LAT IOC to assist in instrument monitoring***
  - *IOC's can also call up MOC ITOS displays over the Internet (MOC Web server)*
- ***Autonomous downlink of burst alerts or safe-mode telemetry using Space Network Demand Access System***



Ops Scenarios: Nominal Supports

Activities	Staffed MOC	Un-Staffed MOC
Pre-Pass:		
Establish and verify connection with TDRSS	✓	✓
Ku-band/S-band transmitters powered on via ATS command	✓	✓
During the pass:		
Verify good two-way comm. with TDRSS	✓	✓
Monitor R/T telemetry for limit/configurations violations	✓	✓
Begin SSR playback via ground command	✓	✓
Load ATS loads, R/T commands, FSW loads, instrument tables, etc.	✓	
Stop SSR playback, turn off transmitters via ATS command	✓	✓
Post pass:		
Ku front end pushes data to the MOC within 2 hours	✓	✓
Archive all transfer frames	✓	✓
Perform data accountability	✓	✓
Process and transfer Level 0 files to MOC file server	✓	✓
Key parameters from ITOS file playback sent to data trending and analysis system	✓	✓

Target of Opportunity Handling

- ***Upon receiving authorization to proceed with the ToO, the GSSC constructs the ToO Order and forwards to the MOC***
  - *GSSC checks for constraint violations, occultation, availability, etc.*
  - *Approved ToO Order is sent to the MOC*
- ***MOC recognizes ToO Order and notifies appropriate FOT personnel for action***
  - *FOT processes ToO Order*
  - *Works with SN to schedule a forward link via TDRSS*
  - *MOC transmits the ToO commands to the spacecraft as soon as the SN forward link is available*
  - *Observatory autonomously returns to on-board observing schedule at completion of the ToO*

Target of Opportunity Handling

ToO Command(s)

TDRS

HK Telemetry

Proj Sci approves the ToO request

Spacecraft receives ToO Command(s)

T0 T1 T2 T3

+ 6 hrs max

T0 -> T1 GSSC generates ToO order (<1 hour)

T1 -> T2 FOT activities (<4 hours)

- FOT staffs the MOC (if ToO occurs Off-Shift)
- scheduling SN resources
- ToO activity/command preparation

T2 -> T3 FOT supports SN contact, spacecraft receives ToO command(s) (<1 hour)

White Sands Complex

Flight Ops Team

ToO Page Alert

ToO Commands, HK Telemetry

FOT staffs MOC

Project Scientist

ToO Request

GSSC

ToO Order

MOC

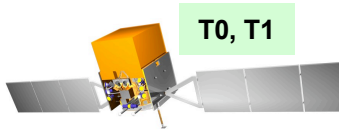
SN MAF Scheduling Coordination

SN Scheduling (SWSI)

Burst Alert Handling

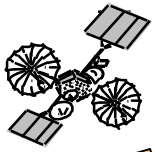
- ***Spacecraft initiates link with TDRSS/DAS, and sends Burst Alert packets as received from instruments***
  - *Burst Alerts go through the Ku-band link if GLAST is in a Ku-band contact*
  - *Burst Alerts go through S-band link if GLAST is in a ground station contact*
  - *If the GRB warrants, LAT requests spacecraft to slew to the target (referred to as an Autonomous Repoint)*
- ***SN forwards messages to MOC, which pulls out Burst Alert packets and forwards to:***
  - *Burst Alert Processor (BAP) located with the MOC and in the GIOC*
  - *BAP processes the messages from both instruments and creates Gamma-Ray Coordinates Network (GCN) Notices*
  - *BAP and GIOC forward the GCN notices to the science community via Gamma-Ray Coordinates Network*
- ***Burst Alerts are sent to a single location i.e. the MOC***
  - *Burst Alerts received by multiple locations (SN and GN)*
  - *Prefer to centralize Burst Alert frame processing*

Burst Alert Handling (cont.)



T0, T1

DAS: Burst Alerts
(1 kbps)



TDRS

GN link
(if in a contact)

Inst. sends Burst Alert on 1553 Bus

Spacecraft transmits to either TDRSS or Ground station

GCN Notices arrive at GCN

T0
0 sec.

T1

T2

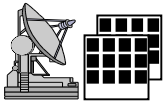
T3
+7 sec.

T0 -> T1 Inst. To Spacecraft transmission <1 second.

T1 -> T2 Space-ground link transmission <5 seconds.

T2 -> T3 Ground system to GCN transmission <1 second.

Ground Stations
WPS, Mila, USN



White Sands Complex

T2

Burst Alerts
(frames)

Burst Alerts
(packets)

GBM
IOC

MOC

GCN notices

Burst Alerts
(packets)

GCN notices

GCN

T3

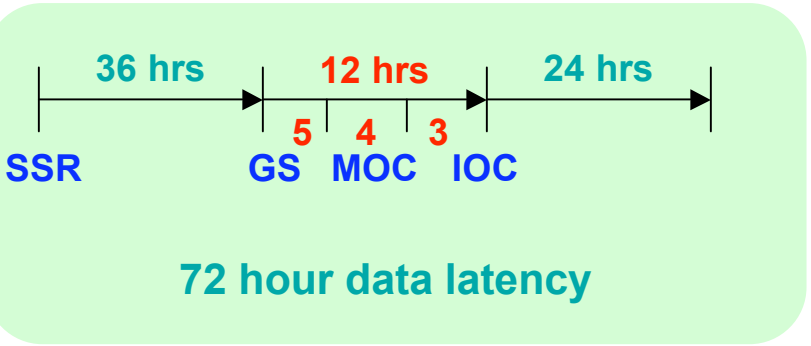
BAP

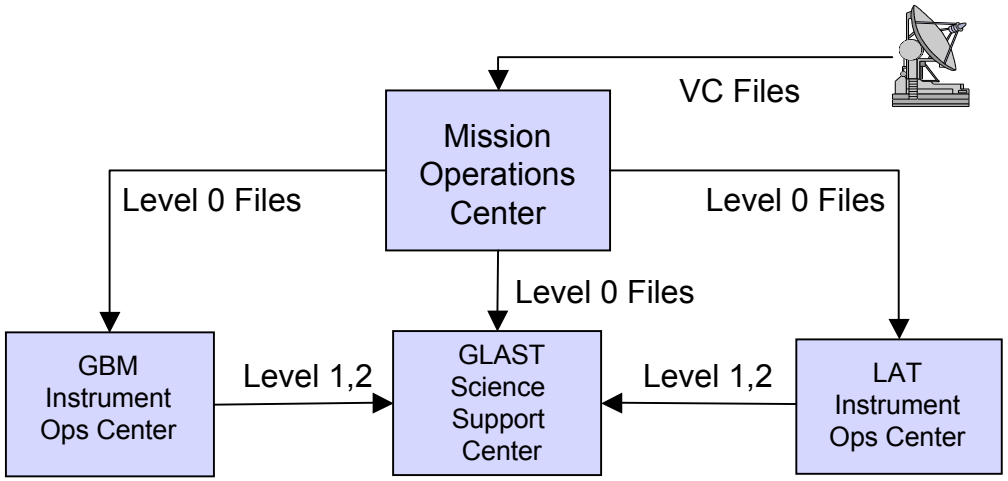
Solid State Recorder Management

- ***Two distinct types of on-board data stored in recorder: Science and Housekeeping***
  - ***Stored in two separate partitions (i.e., two virtual recorders)***
  - ***Dumped separately, but simultaneously***
    - *40 Mbps Ku-band link*
    - *Cannot dump LAT or GBM Science data individually – must dump both*
- ***SSR holds 96 Gbits (~65 hours) of data***
- ***At 40 Mbps, require a minimum of 4 contacts per day (avg 6 minutes per contact) to ensure adequate downlink time***
  - ***Operations will plan for 4-5 contacts to account for anomalies or missed supports***
- ***MOC will initiate SSR playbacks via automated ground commands***
- ***During all contacts, MOC automatically monitors RF-related statistics and SSR pointers in Housekeeping telemetry***
  - ***FOT notified for problems detected that require operator interaction***
- ***MOC makes assessment of data completeness once frame files received from the SN or ground stations***
  - ***Again, operators notified if significant problems detected***

Data Processing

- ***Level 0 processing performed on a dump file basis***
  - ***Ku-band FE records frame-level data during each TDRSS contact, sorts by VCID, and automatically transfers to MOC post-contact***
  - ***MOC automatically begins Level-0 processing on files as they are received from the SN or ground station***
    - *Extraction of packets from frames, Reed-Solomon (RS) decoding, time ordering of data, removal of duplicate packets, and quality and accounting information.*
    - *Upon completion of Level 0 processing the files are sent to MOC file server*
    - *GSSC and IOCs notified that files are ready for transfer*
  - ***IOC's generate Level 1 and 2 data products and provide to GSSC***





Off-line Analysis

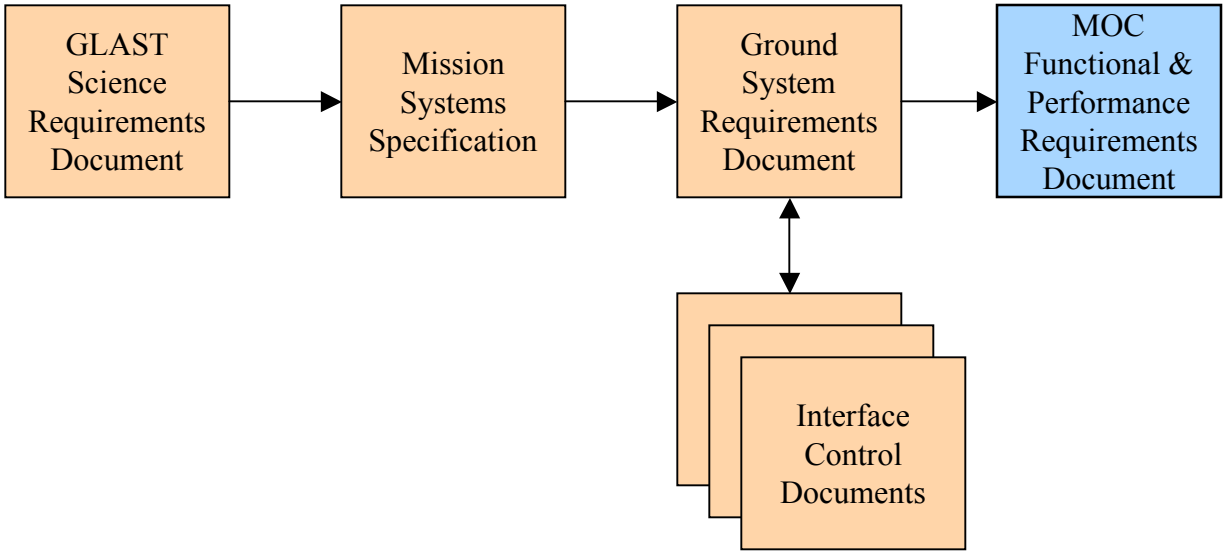
- ***MOC Data Trending and Analysis***
  - ***Selected spacecraft and instrument housekeeping parameters are ingested into a database***
  - ***System provides off-line trending, analysis, and plotting capabilities***
  - ***System provides remote access to users such as FOT, Spectrum Astro, or IOC personnel***
- ***As-Flown Timeline***
  - ***Since GLAST has the ability to autonomously deviate from the pre-planned science timeline it is necessary to track deviations or unplanned activities such as Auto-Repoint targets or ToOs.***
  - ***MOC generates an As-Flown Timeline based on what observatory actually did on orbit***
  - ***Contents to be defined in the Operations Data Products ICD***
    - *As-flown timeline used by both the IOCs and GSSC*
  - ***Created entirely from observatory housekeeping telemetry***
  - ***Intended to be a high level record of the actual observatory observations***

MOC Requirements

J.D. DeGumbia

MOC Requirements

Requirements Flow



The MOC Functional & Performance Requirements Document represents a 4th level of the GLAST project requirement hierarchy

MOC Requirements

Requirements Development Methodology

- ***Requirements written to allow the MOC to be designed, constructed, tested, and operated***
- ***MOC requirements originate from GSRD requirements and their intent***
- ***3 development approaches taken to ensure a complete MOC requirement set***
  - ***Top-down - Each GSRD requirement relating to the MOC is functionally decomposed to improve detail and advance conceptual design. Bi-directional traceability maintained.***
  - ***Bottom-up - Requirement set scrutinized for necessary functions that are not directly traceable to GSRD requirement. Requirements added as necessary.***
  - ***Associative – Requirements of similar projects (Swift) are analyzed and compared to MOC requirements to identify deficiencies. Requirements added as necessary.***

MOC Requirements

MOC Requirements Development History

- ***MOC requirements development initiated immediately following the completion of the GSRD baseline.***
- ***Requirements document reviewed internally within MOC development team.***
- ***Draft version of requirements document distributed to ground system team on November 13, 2003.***
- ***Document has undergone internal reviews with the ground systems team***
- ***Prior to being baselined the document will be updated as mandated by changes in GSRD, ICDs, or agreements with interfacing elements.***
- ***After being baselined the requirements document will be maintained through the Ground System CCB.***
  - ***When deficiencies are found in the MOC requirements***
  - ***When changes affecting MOC requirements are made to the GSRD.***

MOC Requirements

Requirements Statistics

Functional Area	*Number of Requirements*	*Section Number*
MOC Configuration and Architecture	**117**	**3.1**
Mission Planning and Scheduling	**183**	**3.2**
Telemetry & Command Processing	**214**	**3.3**
Monitoring & Analysis	**220**	**3.4**
Total	**734**	

MOC Key Requirements

3.1 MOC Configuration and Architecture

- ***Furnish MOC facility with equipment necessary to control GLAST observatory***
- ***Provide redundancy for all MOC functions and data***
  - *Automatic failover to backup systems of components supporting real-time operations within 1 minute*
  - *Manual failover to backup systems of components supporting non-real-time operations within 30 minutes*
  - *Restore backup capabilities within 12 hours*
- ***Provide capability to support single 8x5 staffed shift and operate autonomously whenever not staffed***
  - *Automated pass execution (including SSR dumping)*
  - *Automated Level 0 data processing and posting*
  - *Automated telemetry monitoring*
  - *Automated monitoring of ground systems*
  - *Automated alarm detection and notification of on-call personnel for Observatory or ground system anomaly*
- ***Provide a reliability of 99.98% for launch critical functions***
- ***Allow maintainability with no loss of performance for life of mission***
- ***Comply with NPG 2810.1 Information Technology (IT) security requirements***

MOC Key Requirements (cont.)

3.2 Mission Planning & Scheduling

- **Routine**
  - Receive science timeline from GSSC once per week
  - Determine possible TDRS view periods
    - Model the observatory attitude based on the science timeline
    - Model antenna pointing capabilities and masking
    - Account for observatory and antenna slew times
  - Combine and deconflict science and engineering needs of the observatory to create the Integrated Observatory Timeline
  - Schedule SN & GN resources for RF comm with Observatory so as not to impact science data gathering
  - Generate orbit products for planning tools and for SN/GN acquisition
  - Build stored command loads (ATS & RTS loads) based on Integrated Observatory Timeline within 2 hours
- **Non-routine**
  - Re-schedule in response to Autonomous Repoints as necessary
  - Receive FSW loads from Spacecraft Bus Team & IOCs, schedule uplink
  - Receive Instrument command requests from GSSC/IOCs, schedule uplink
  - Receive ToO orders from the GSSC, schedule and execute uplink within 4 hours.

MOC Key Requirements (cont.)

3.3 Telemetry & Command Processing

- ***Provide sole interface between ground system elements and space-ground comm links***
  - *Interface with TDRSS DAS & WDISC, ground stations*
- ***Generate and uplink all commands to the Observatory***
  - *R/T commands, ATS & RTS loads, tables, FSW loads*
  - *Verify commands against constraints prior to uplink*
  - *Support CCSDS compliant commands, COP-1 verification protocol*
- ***Receive, process and archive Observatory telemetry***
  - *Support CCSDS compliant telemetry*
  - *Receive R/T telemetry from ground stations and TDRSS*
  - *Receive recorded telemetry from ground stations post-pass*
  - *Archive all CCSDS frames for life of mission*
  - *Decommutate and process housekeeping telemetry*
  - *Provide R/T telemetry displays for local and remote users*
  - *Monitor spacecraft & instrument housekeeping TLM for health & safety then notify appropriate personnel as necessary.*
  - *Receive and process S/C & instrument onboard processor memory dump data*

MOC Key Requirements (cont.)

3.3 Telemetry & Command Processing (cont.)

- **Science Data Processing**
  - **Generate Level 0 telemetry data sets**
    - *Packet files created following each pass*
    - *Level 0 packet files are time-ordered, duplicate removed on a per pass basis*
    - *Archive level 0 data sets for minimum of 7 days*
  - **Provide GSSC and IOCs access to Level 0 files within 4 hours of receipt from ground stations**
  - **Process Level 0 files at a rate of 20 GBytes/day**
    - *> 5 times the observatory daily data generation rate*
  - **Generate telemetry frame quality statistics & log missing frames**
  - **Schedule re-dumps of science data as necessary**
    - *The MOC must not contribute a data loss of more than 1% of total data volume.*

MOC Key Requirements (cont.)

3.3 Telemetry & Command Processing (cont.)

- **Alert Handling**
  - **Burst Alerts**
    - Receive burst alert telemetry
    - Forward alert telemetry to BAP and to the GIOC (initiate within .5 seconds)
    - Log Burst Alerts
  - **Autonomous Re-points**
    - Receive indication of Autonomous Re-points
    - Notify science ops and FOT personnel
    - Re-plan observatory schedule and passes as necessary
    - Log Autonomous re-points & note in As-flown Timeline
  - **Observatory alarm messages**
    - Receive indication of observatory alarm message
    - Log alarm message
    - Page FOT personnel within 5 minutes
    - Notify science personnel

MOC Key Requirements (cont.)

3.4 Monitoring & Analysis

- ***Monitor ground system processes, page on-call personnel as appropriate***
  - *Internal MOC processes*
  - *External ground system elements (as available)*
- ***Display pages & graphs of real-time and playback HK telemetry***
- ***Provide limit and configuration monitoring of HK telemetry***
- ***Provide event message logging and delogging***
- ***Generate As-flown Timeline from stored HK data***
  - *Provide as-flown timeline to GSSC covering a 24-hour period within 7 days*
- ***Provide automated alarm detection, page/email on-call personnel as appropriate***

MOC Key Requirements (cont.)

3.4 Monitoring & Analysis (cont.)

- ***Provide memory mapping & maintenance capabilities***
  - *Maintain a copy of uploaded images for life of mission*
  - *Provide ability to dump and compare uploaded images*
  - *Provide dumped images to software maintenance teams*
- ***Provide capability to perform trending & analysis of housekeeping data***
- ***Provide web access for remote users to telemetry, trending data & other MOC products***
  - *Timelines, contact schedules, command logs, event logs, orbit data, anomaly reports, etc*
- ***Support sustaining engineering of observatory & ground system***
  - *Maintain MOC facility systems: hardware & software*
  - *Maintain CM of TLM & CMD database, PROCs, display pages, configuration monitors, MOC documentation, etc.*

MOC Requirements Verification

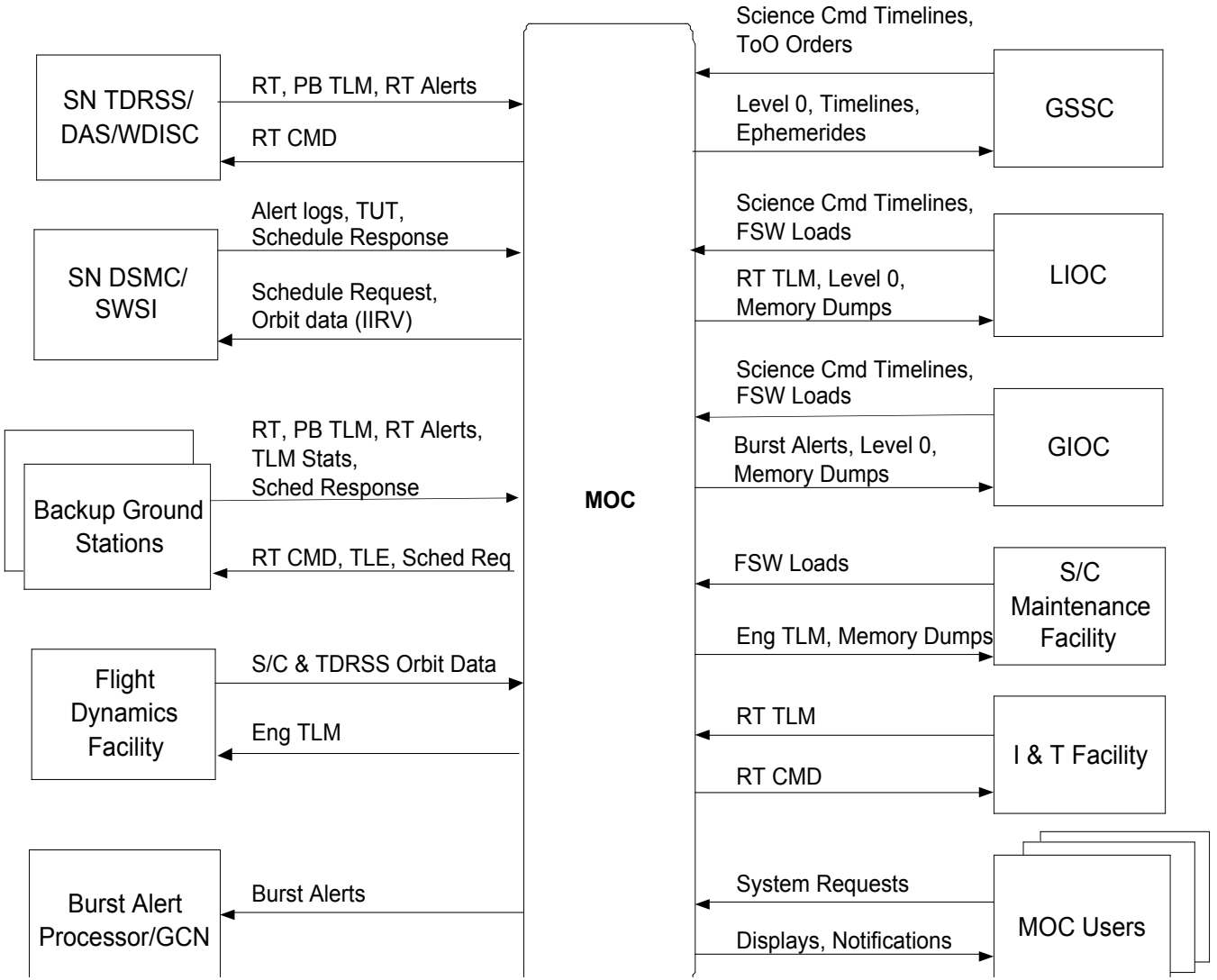
Requirements Verification Matrix

- ***Requirements Verification Matrix will be created from the MOC requirements***
- ***For each requirement in the table a separate columns will track***
  - ***Allocations to software components***
  - ***Allocations to software builds***
  - ***Validation method - Analysis, Inspection, Test, or Demonstration***
  - ***Associated test case/procedure***
- ***Matrix will be maintained in parallel to the MOC requirements document***
- ***Matrix will serve as primary tool for tracking the verification & validation status of each requirement as tested at the element level***
- ***Matrix will be created by SDR***

MOC Design

Marilyn Mix

External Interfaces



MOC External Interfaces (1 of 4)

- ***SN TDRSS***
  - *Provides communication services through TDRSS*
  - *Real-time return link low-rate data (burst alerts, emergencies, housekeeping) via Demand Access Service (DAS) 24 hour service*
  - *Commanding and telemetry via scheduled TDRSS service*
- ***SN SWSI/NCC***
  - *Scheduling of SN services and obtaining performance data (DAS & WDISC) via SN Web Services Interface (SWSI) to DSMC*
- ***Flight Dynamics***
  - *Early mission phase: Flight Dynamics Facility (FDF) provides orbit determination based on TDRSS tracking data*
  - *Remainder of mission: GPS position via telemetry (primary) or NORAD Two Line Element (TLE) sets provided by the NASA Orbital Information Group (OIG) web site (backup)*

MOC External Interfaces (2 of 4)

- ***Backup Ground Stations***
  - *Provide backup commanding and telemetry*
  - *USN: Hawaii and Australia*
  - *Wallops: Wallops Island, VA*
  - *MILA: Merritt Island, FL*
- ***Burst Alert Processor (BAP)***
  - *Burst Alert packets*
- ***GLAST Science Support Center (GSSC)***
  - *Provides ToO orders, science activity timelines and loads to MOC*
  - *MOC provides the Level 0 products, ephemerides and timelines to the GSSC for processing into higher level science products*

MOC External Interfaces (3 of 4)

- ***LAT Instrument Operation Center (LIOC)***
  - *Stanford Linear Accelerator Center (SLAC), Palo Alto, CA*
  - *LIOC provides science activity timelines and FSW loads via GSSC or directly to the MOC*
  - *MOC provides real-time and engineering telemetry*
  - *MOC provides memory and table dump data for analysis and troubleshooting*
- ***GBM Instrument Operation Center (GIOC)***
  - *University of Alabama-Huntsville, AL.*
  - *GIOC provides science activity timelines and FSW loads via GSSC or directly to the MOC*
  - *MOC provides burst alert packets and engineering telemetry*
  - *MOC provides memory and table dump data for analysis and troubleshooting*
- ***Spacecraft Maintenance Facility***
  - *Spectrum Astro, Gilbert, AZ*
  - *Spectrum Astro provides FSW maintenance and sustaining engineering services*
  - *MOC provides engineering telemetry, memory and table dump data for analysis and troubleshooting*

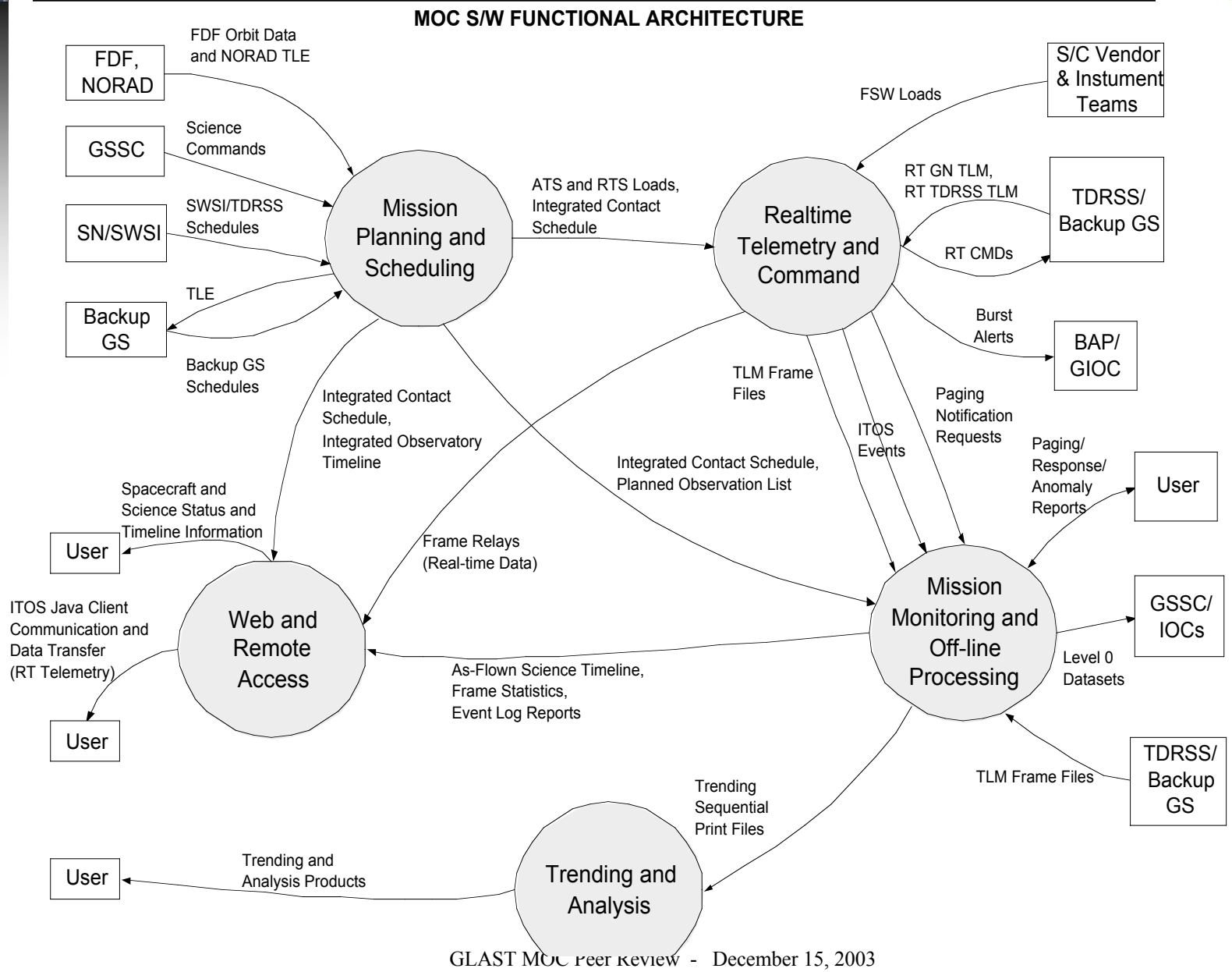
MOC External Interfaces (4 of 4)

- ***Integration and Test Facility (Pre-Launch)***
  - *Spectrum Astro, Gilbert, AZ*
  - *Spectrum Astro provides realtime telemetry (spacecraft or simulator)*
  - *MOC provides realtime commands and loads*
- ***MOC Users***
  - *Authorized users including Flight Operations Team (FOT), S/C vendor, science and instrument teams*
  - *View real-time telemetry data and events and access stored telemetry data*
  - *Mission scheduling activities and commanding*

External Interface Documentation

Interface	*Document Title*	*Reference Number*
MOC to TDRSS DAS	*ICD Between the DAS and the DAS Customers*	453-ICD-DAS/Customer
MOC to TDRSS WDISC	*Interface Control Document Between the Network Control Center Data System and the Mission Operations Centers* *WSC Transmission Control Protocol (TCP)/Internet Protocol (IP) Data Interface Service Capability (WDISC) User's Guide*	451-ICD-NCCDS/MOC 452-WDISC-UG 98
MOC to Backup Ground Station	*GLAST MOC to Backup Ground Station Interface Control Document*	492-MOC-010
MOC to SWSI	*SN SWSI Client User's Guide*	452-UG-SWSI
MOC to GSSC, GIOC, LIOC, BAP	*MOC Operations Data Products ICD*	492-MOC-009
MOC to FDF	*Interface Control Document Between the FDF and the GLAST MOC*	
MOC to S/C Vendor Facility	*GLAST Spacecraft to MOC Interface Control Document*	
MOC to MOC Users	*GLAST MOC User Guide*	

Software Architecture



MOC Subsystem Descriptions (1 of 3)

- ***Mission Planning & Scheduling***
  - ***Responsible for producing a planned set of spacecraft commands needed to perform science observations and spacecraft housekeeping.***
    - *GN/SN Contact Scheduling*
    - *Orbit Determination & Orbital Events Generation*
    - *Observatory Timeline & Command Load Generation*
- ***R/T Telemetry & Command Processing***
  - ***Responsible for the receipt, processing, distribution of real-time telemetry and transmitting commands to the spacecraft***
    - *Automated Pass Plan Execution*
    - *Command Uplink & Verification*
    - *Telemetry Downlink, Processing, Display & Distribution*
    - *Limit Checking & Configuration Monitoring*
    - *System Event Generation*

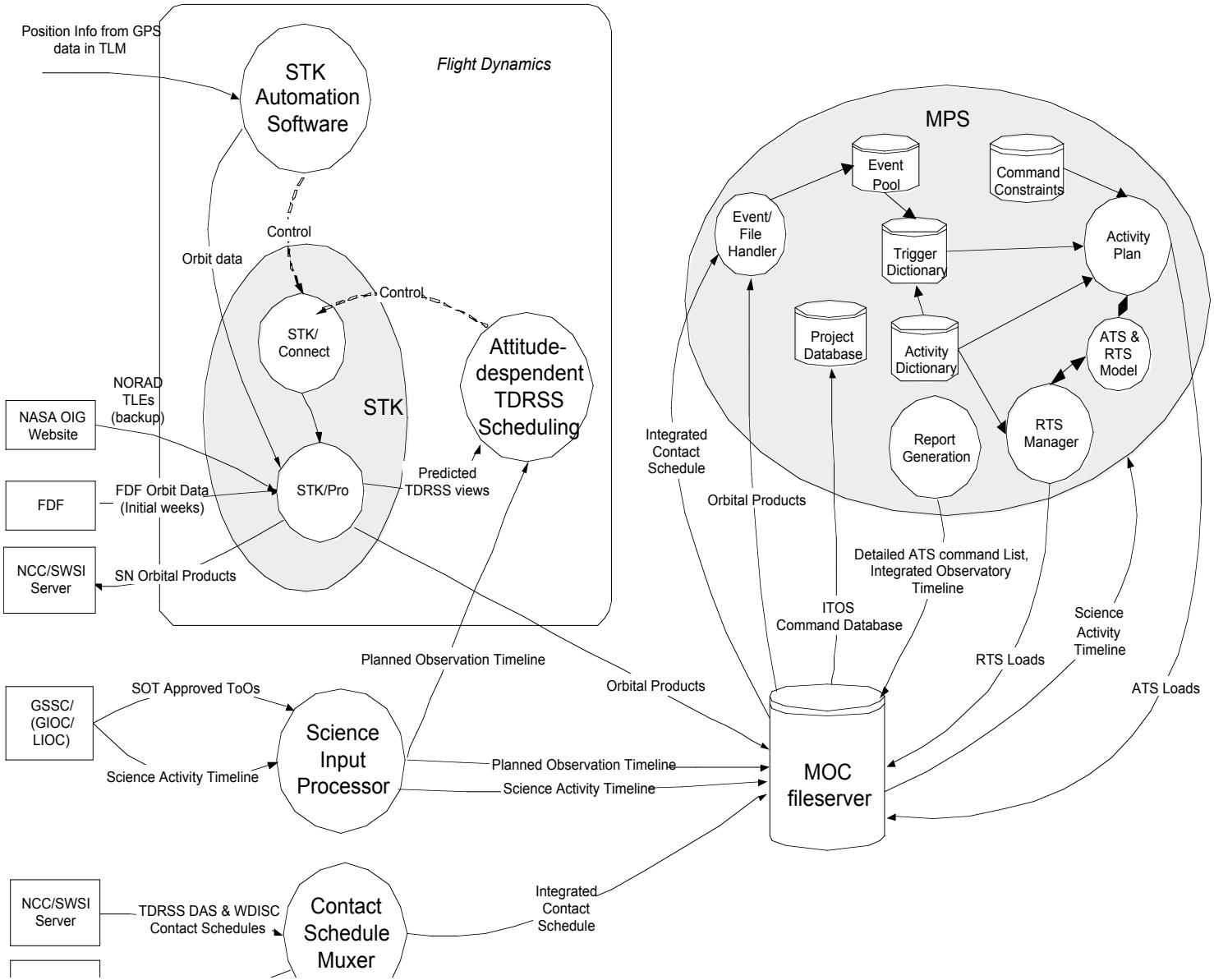
MOC Subsystem Descriptions (2 of 3)

- ***Mission Monitoring and Offline Processing***
  - ***Responsible for the processing of playback telemetry, collecting and logging telemetry statistics and the archiving of MOC files.***
    - *Monitor Events for Anomalous Conditions*
    - *Automatic Notification to On-call Personnel for Emergencies*
    - *Timeline Execution Verification*
    - *Level 0 Processing, Archive & Distribution*
    - *Data Accountability & Quality Statistics*
- ***Trending & Analysis***
  - ***Responsible for the trending and analysis of downlinked telemetry data for the evaluation of spacecraft and instrument health and safety.***
    - *Generate trend data, accumulated over life of mission*
    - *Generate plots, reports, statistics on selected telemetry data*

MOC Subsystem Descriptions (3 of 3)

- ***Web and Remote Access***
  - ***Responsible for providing the primary point of access for outgoing data and information from the MOC to external users.***
    - *Remote ITOS displays*
    - *Remote Trending (DTAS) access*
    - *Anomaly Reports*
    - *MOC Web Site*

Mission Planning and Scheduling



MP&S Subsystem Software Components

- ***Satellite Tool Kit (STK)***
  - *COTS*
  - *STK/Professional (STK/PRO) module for orbit propagation and analysis*
  - *STK/Connect module to control/communicate with STK/PRO*
  - *Creates ephemerides, TDRSS and GS view period and orbit event files*
- ***STK Automation Software***
  - *Reuse from Swift with significant modification*
  - *Controls STK operation*
    - *Initiates ephemeris generation*
    - *Initiates orbital products generation*
  - *Extracts S/C GPS orbit data from telemetry. (new for GLAST)*
  - *Passes S/C position data to STK, and to the public Web Server*
  - *As a backup, retrieves the new NORAD Two Line Element (TLE) sets from the NASA Orbital Information Group (OIG) web site*

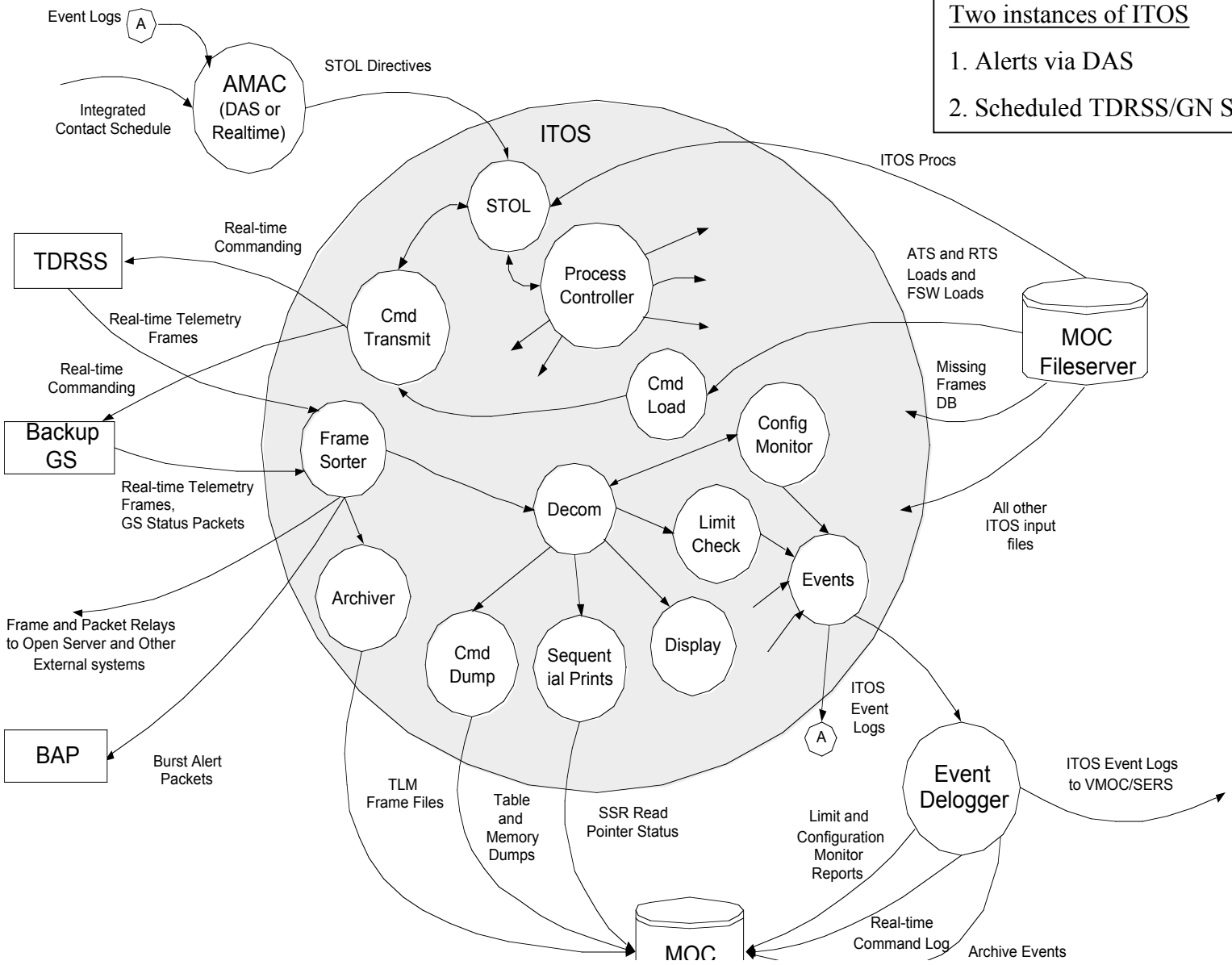
MP&S Subsystem Software Components

- ***Attitude-Dependent TDRSS Scheduling***
  - *New software*
  - *Uses planned observation list to create a predicted attitude file*
  - *Uses STK to produce GLAST to TDRSS view reports, based on the predicted attitude file, a spacecraft antenna mask defined in STK, the predicted orbit ephemeris for GLAST and TDRSS*
  - *FOT schedules TDRSS based on view reports*
- ***Contact Schedule Muxer***
  - *Reuse from Swift*
  - *Creates the Integrated Contact Schedule*
  - *Combines the TDRSS and ground station contact scheduling information into the same time-ordered format, in a single file*

MP&S Subsystem Software Components

- ***Science Input Processor***
  - *New software*
  - *Stores files from GSSC and IOCs into appropriate MOC directories*
  - *Converts science activity timeline to a planned observation timeline*
- ***MPS***
  - *Reused GOTS, with modifications*
  - *Generates stored command loads (ATS and RTS)*
  - *Produces the Integrated Observatory Timeline*
  - *Merges science activity list with engineering commands into a load plan*
  - *Supports alternate loads per planning period*
  - *Maintains a stored command memory map for ATS and RTS tables*
  - *Stores named sets of commands for reuse (activity macros)*
  - *User configurable*

Real-Time Telemetry & Command



Real-time Telemetry & Command Subsystem Software Components

- ***Integrated Test and Operations System (ITOS)***
  - ***Controls the spacecraft and spacecraft components as well as the receipt and processing of telemetry data***
  - ***GOTS, maintained by GSFC Code 584***
  - ***Controlled manually or by AMAC***
  - ***Reads ITOS STOL Procs to control:***
    - *Telemetry acquisition*
    - *Sending of spacecraft real-time commands*
    - *Display of telemetry pages*
  - ***Sorts by time and removes any duplicate real-time frames. Sorts GS frame statistics and status packets for each VC***
  - ***Relays frames to ITOS executing on the Web and Remote Access Subsystem***
  - ***Sends Burst Alert packets to BAP, GIOC, etc.***
  - ***Archives of realtime and alert telemetry frame files.***
  - ***Decommutates telemetry packets into:***
    - *S/C or instrument table and memory dump data*
    - *ITOS event logs*

Real-time Telemetry & Command Subsystem Software Components

- ***DAS Automation Monitoring and Control (AMAC)***
  - ***Controls all aspects of real-time telemetry processing for the TDRSS Demand Access System (DAS) service.***
  - ***Based on Swift software, with mission-specific modifications***
  - ***Initiates a copy of ITOS to process data from DAS.***
  - ***Uses Space Network Web Services Interface (SWSI) TDRSS schedule to determine the kind of processing to perform.***
  - ***Processes ITOS Event Logs***
    - *Generates statistical reports for display by ITOS or web interface*
    - *Erroneous conditions reported to Virtual Mission Operations Center/Spacecraft Emergency Response System VMOC/SERS for paging*
  - ***SWSI alert logs***
    - *Selected SWSI alerts routed to paging/notification system*

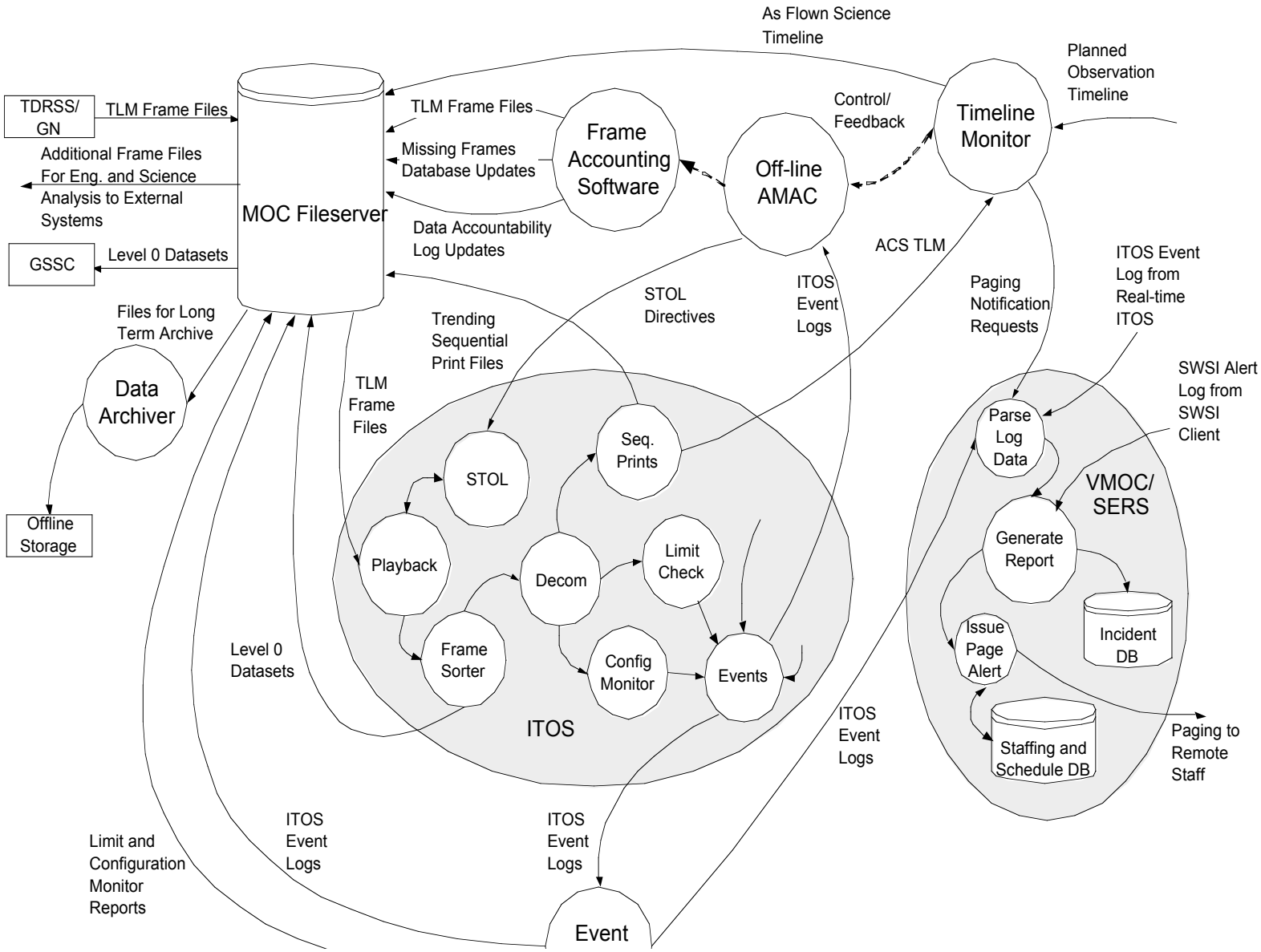
Real-time Telemetry & Command Subsystem Software Components

- ***Realtime Automation Monitoring and Control (AMAC)***
  - ***Controls all aspects of real-time telemetry processing for the scheduled TDRSS contacts***
  - ***Based on Swift software, with mission-specific modifications***
  - ***Starts a copy of ITOS according to the contact schedule***
    - *Initiates the appropriate STOL PROC*
  - ***Processes ITOS Event Logs***
    - *Generates statistical reports for display by ITOS and web interface*
    - *Erroneous conditions reported to Virtual Mission Operations Center/Spacecraft Emergency Response System VMOC/SERS for paging*
  - ***Creates and processes the Scheduled Contact Task List***
    - *Based on the contact schedule, and edited by user as necessary.*
    - *Updates contact status for display by ITOS and web interface*

Real-time Telemetry & Command Subsystem Software Components

- ***Real-time Event Delogger***
  - ***Generates custom reports from ITOS event logs***
  - ***Reuse from Swift***
  - ***Scheduled to run every 5 minutes to handle any Alert messages (GRB, etc.)***
  - ***Creates automated reports from the ITOS event logs***
    - *Limit violations report*
    - *Configuration violations report*
    - *Real-time command report*
  - ***Archives the ITOS event logs to the MOC file server***
  - ***Passes the ITOS event logs to the VMOC/SERS for alert processing***

Mission Monitoring & Off-Line Processing



Mission Monitoring and Offline Processing Software Components

- ***ITOS***
  - ***GOTS***
  - ***Playback of CCSDS telemetry frame files for all virtual channels***
  - ***Packet extraction to Level 0 data sets***
  - ***Decommutation of telemetry for limit checking, configuration monitoring, and sequential print generation for trending and timeline processing***
  - ***Generation of event logs***
- ***VMOC/SERS***
  - ***GOTS***
  - ***Receives anomaly messages from all MOC components***
  - ***Parses event logs for anomalies (ITOS, SWSI)***
  - ***Notifies appropriate personnel using two-way paging, email***
  - ***Provides access to anomaly reports and ITOS logs***

Mission Monitoring and Offline Processing Software Components

- ***Timeline Monitor***
  - ***Based on Swift software, extensive modification.***
  - ***Uses telemetry to determine pointing coordinates and modes.***
  - ***Creates preliminary as-flown timeline***
- ***Frame Accounting Software***
  - ***Reuse from Swift***
  - ***Determines and reports frame quality statistics for each frames file***
  - ***Determines gaps in frames and logs those gaps to the Missing Frame Database***

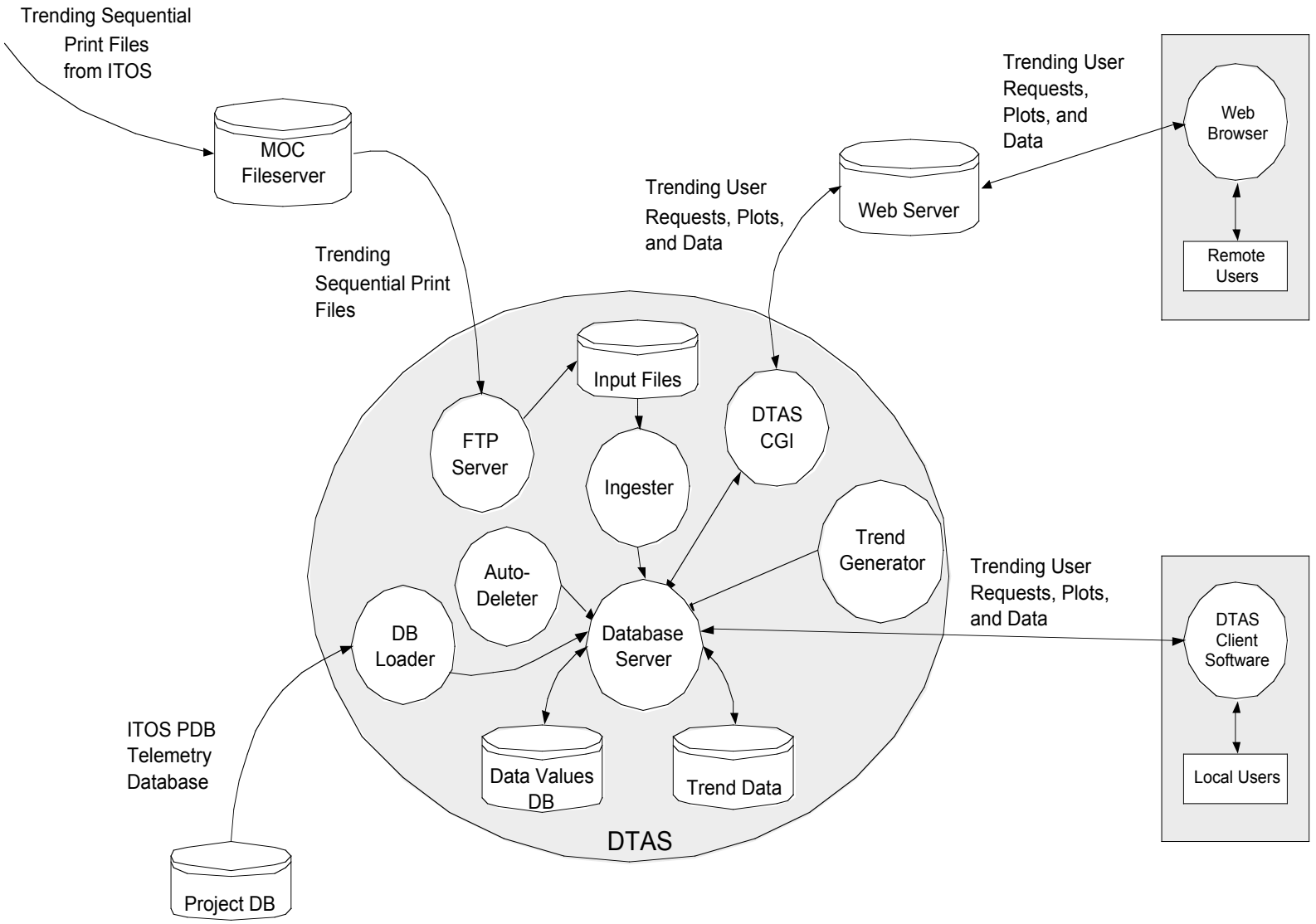
Mission Monitoring and Offline Processing Software Components

- ***Event Delogger***
  - ***Reuse from Swift***
  - ***Generates limit violation, configuration violation and real-time command reports from the ITOS event log***
  - ***Forwards the ITOS event log to VMOC/SERS and the fileserver for archiving***
- ***Data Archiver***
  - ***Compress and archives to off-line media: CCSDS frame files, Integrated Observatory Timeline files, and sequential print files***

Mission Monitoring and Offline Processing Software Components

- ***Offline Automation Monitoring and Control (AMAC)***
  - ***Based on Swift software, moderate modification***
  - ***Automates control of offline telemetry processing***
  - ***Determines if telemetry files are available for processing***
  - ***Starts ITOS and issues the Offline AMAC ITOS Processing STOL Proc***
    - *controls the ITOS processing of a frame file*
    - *distributes sequential print files to DTAS*
    - *distributes Level 0 products to GSSC*
  - ***Monitors ITOS event log for processing completion and anomalies***
  - ***Upon completion of housekeeping frame processing, starts and monitors the Timeline Monitor***
  - ***Starts Frame Accounting Software***
  - ***Sends anomaly messages to VMOC/SERS***

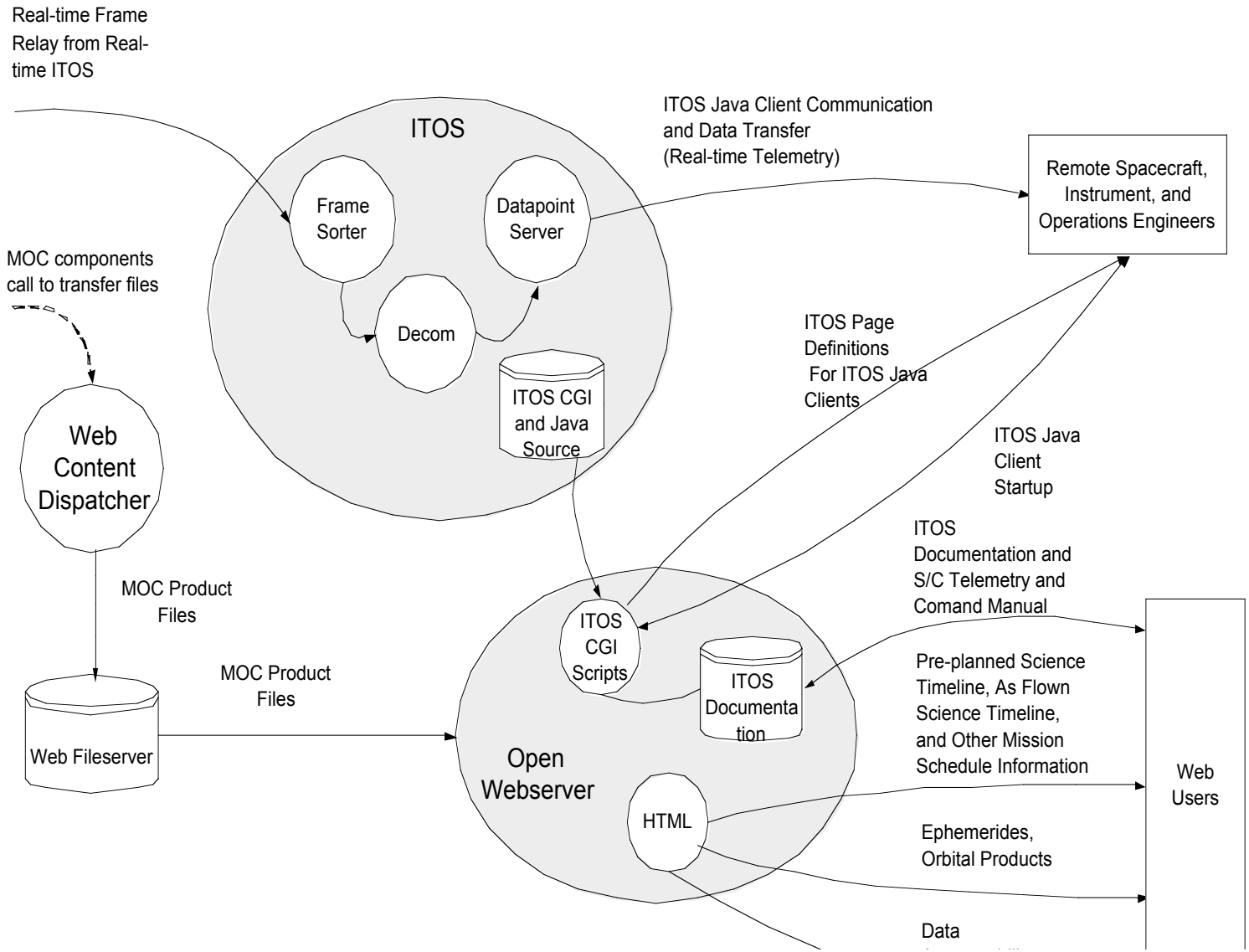
Trending and Analysis



Trending and Analysis Subsystem Software Components

- ***DTAS (Data Trending and Analysis System) Software***
  - *GSFC GOTS package*
  - *Automated ingest of telemetry data and generation of trend data*
  - *Graphical and numeric plotting*
  - *Statistical analysis*
  - *Data export (e.g., to Microsoft Excel for subsequent analysis)*
  - *View, print, and save reports to a file*
  - *Remote data access via Internet*
- ***Local DTAS Clients installed on user workstation (downloadable from MOC Web Server)***
- ***Web-based DTAS Client (limited to single-mnemonic plots)***

Web & Remote Access



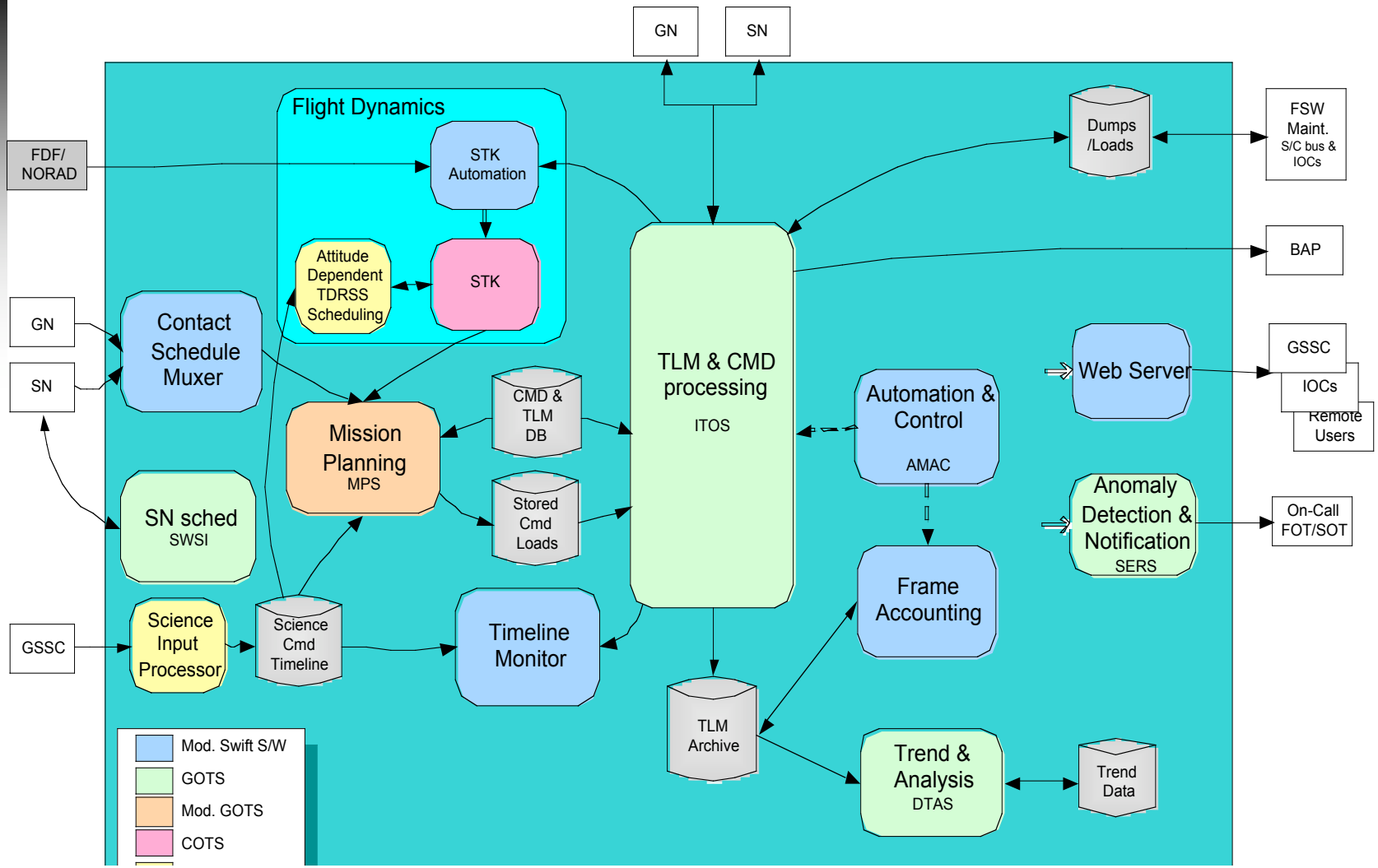
Web & Remote Access Subsystem Software Components

- ***Integrated Test and Operations System (ITOS)***
  - ***GOTS***
  - ***Executes on the open server (i.e., outside the MOC closed subnet)***
  - ***Receives and processes real-time telemetry frames from the Prime R/T ITOS***
  - ***Performs frame sorting and decommutation in order to populate the Current Value Table (CVT) in the ITOS DB***
  - ***Services the streaming of data from the CVT to the ITOS Java client executing at remote locations***

Web & Remote Access Subsystem Software Components

- ***Open Web Server***
  - ***Servicing of GLAST user requests via a web interface***
  - ***Documentation***
  - ***MOC Products***
    - *Documentation*
    - *ITOS Reports and Event Logs*
    - *Flight Dynamics Products*
    - *Timelines and Contact Schedules*
    - *Telemetry Statistics*
    - *Level 0 Products*

MOC Software Components



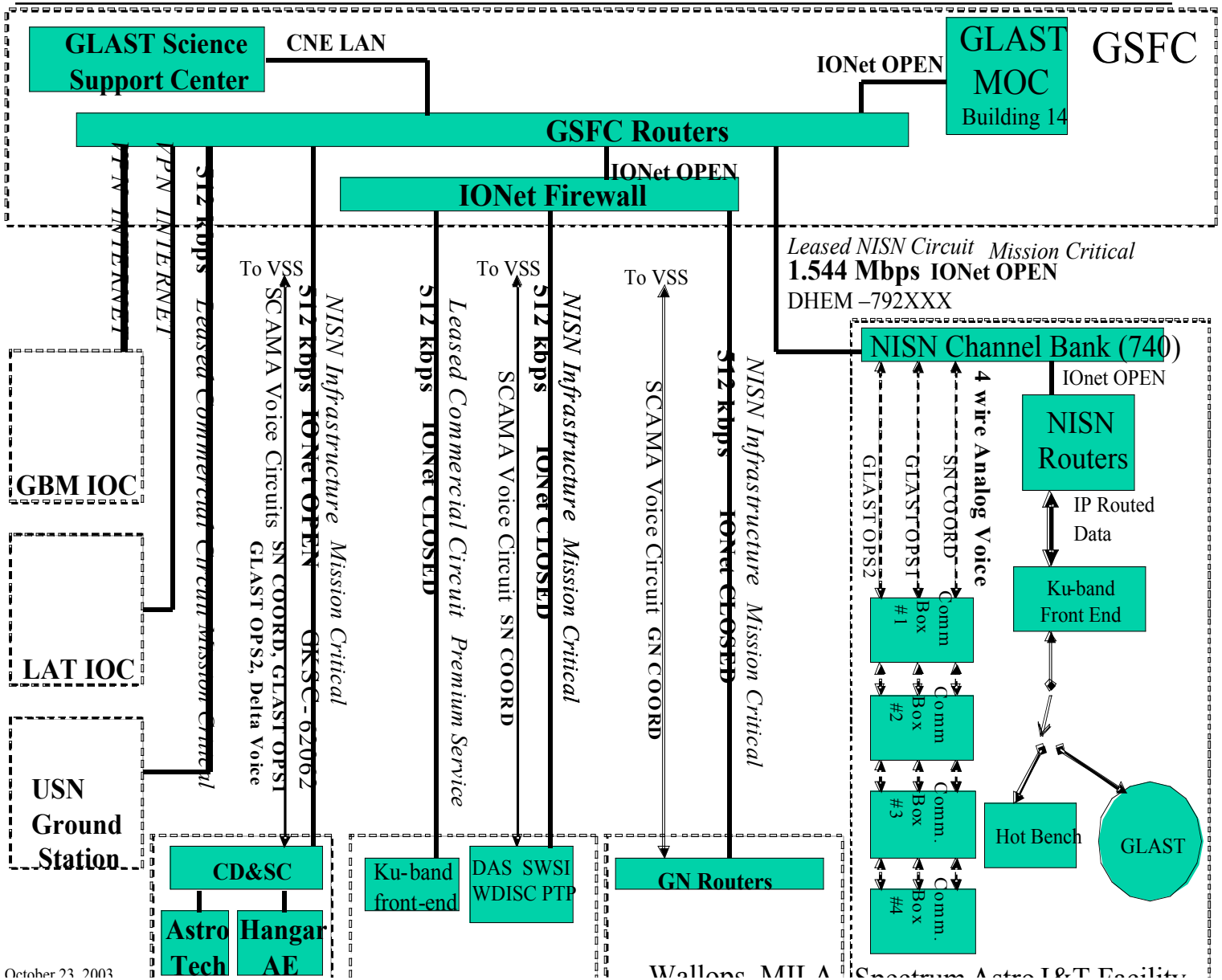
MOC Software Components Summary

SUBSYSTEM	SOFTWARE	SOURCE	HERITAGE
Mission Planning and Scheduling	**MPS** – Mission Planning System	GSFC	TRACE, WIRE, Swift
	STK – Satellite Tool Kit	AGI	GSFC, NORAD
	SWSI Client	GSFC	Swift
	Contact Schedule Muxer	GSFC	Swift (w/ mod)
	STK Automation	GSFC	Swift (w/ mod)
	TDRSS Scheduling (attitude -dependent)		New
	Science Input Processor		New
Realtime Telemetry and Command	**ITOS**- Integrated Test and Operations System	GSFC	SMEX, Swift
	Event Delogger	GSFC	Swift
	AMAC (DAS, Realtime)	GSFC	Swift (w/ mod)
Mission Monitoring and Offline Processing	**ITOS**- Integrated Test and Operations System	GSFC	SMEX, Swift
	VMOC/SERS – Spacecraft Emergency Response System	GSFC	SMEX, MAP, IMAGE, Swift
	Timeline Monitor		New
	Frame Accounting	GSFC	Swift
Trending and Analysis	**DTAS** – Data Trending and Analysis Syst em	GSFC	SMEX, Swift
Web and Remote Access	**ITOS**- Integrated Test and Operations System	GSFC	SMEX, Swift
	Apache – Web Server	Open-source	
	MOC Product Web Page and access scripts		New

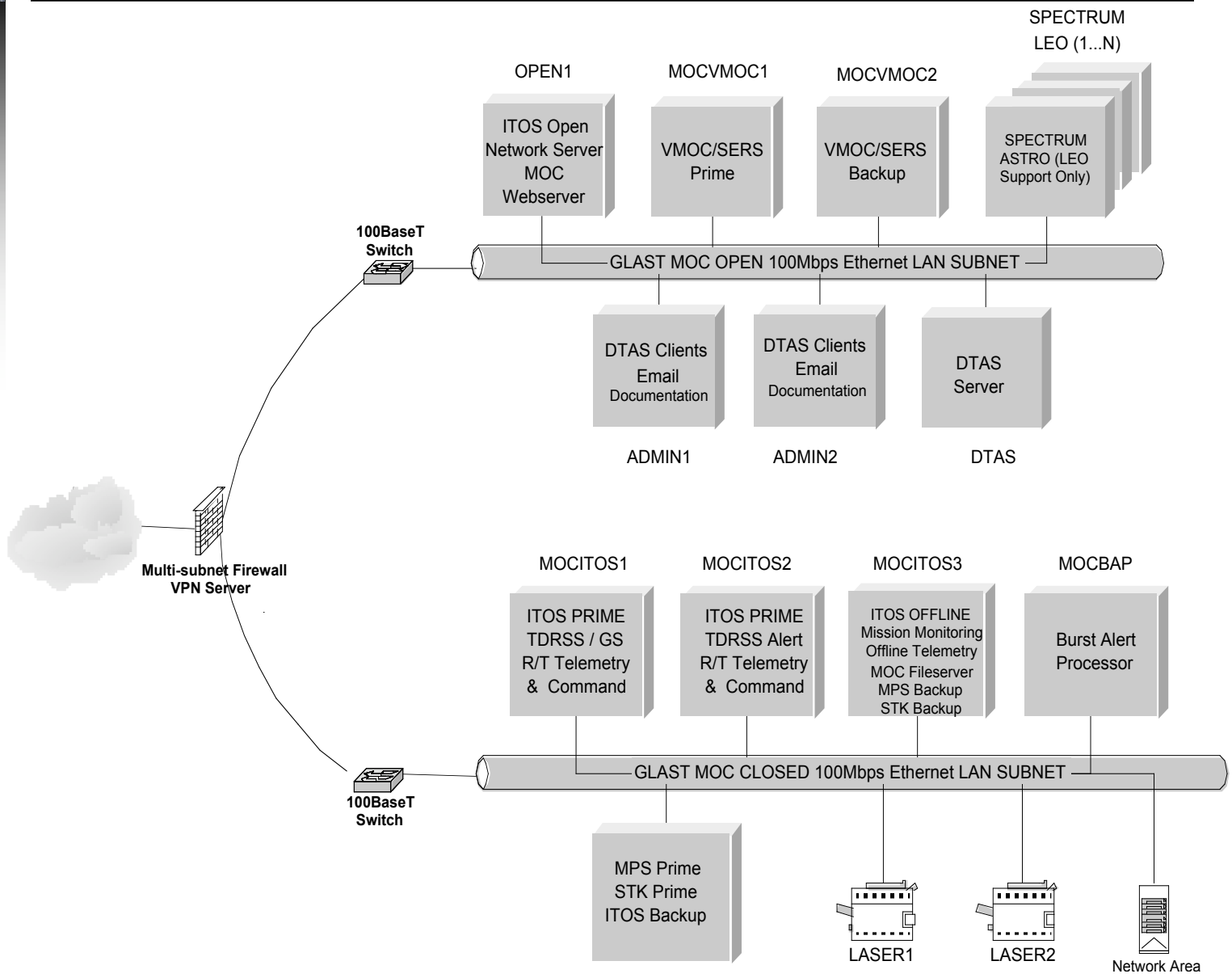
Software Size Estimate

Component	*New/Modified (KLOC)*	*Final Size (KLOC)*
DAS_AMAC	1	2
Contact_Schedule_Muxer	0.5	2
Contact_Schedule_Request		0.5
Event_Delogger		0.5
Frame_Accounting		3.5
Libraries	0.5	8.5
MPS	1	152
Offline_AMAC	0.5	2.5
Realtime_AMAC	1	2
Science_Input_Processor	2.5	2.5
STK_Automation	2	6
Task_Schedule_Editor	0.5	3.5
TDRSS_Scheduling	5	5
Timeline_Monitor	3	3
Web_Access	1	1
Web_Content_Dispatcher	0.2	0.5
TOTAL	**19.7**	**195**
w/o MPS	**18.7**	**43**

GLAST Communications Architecture

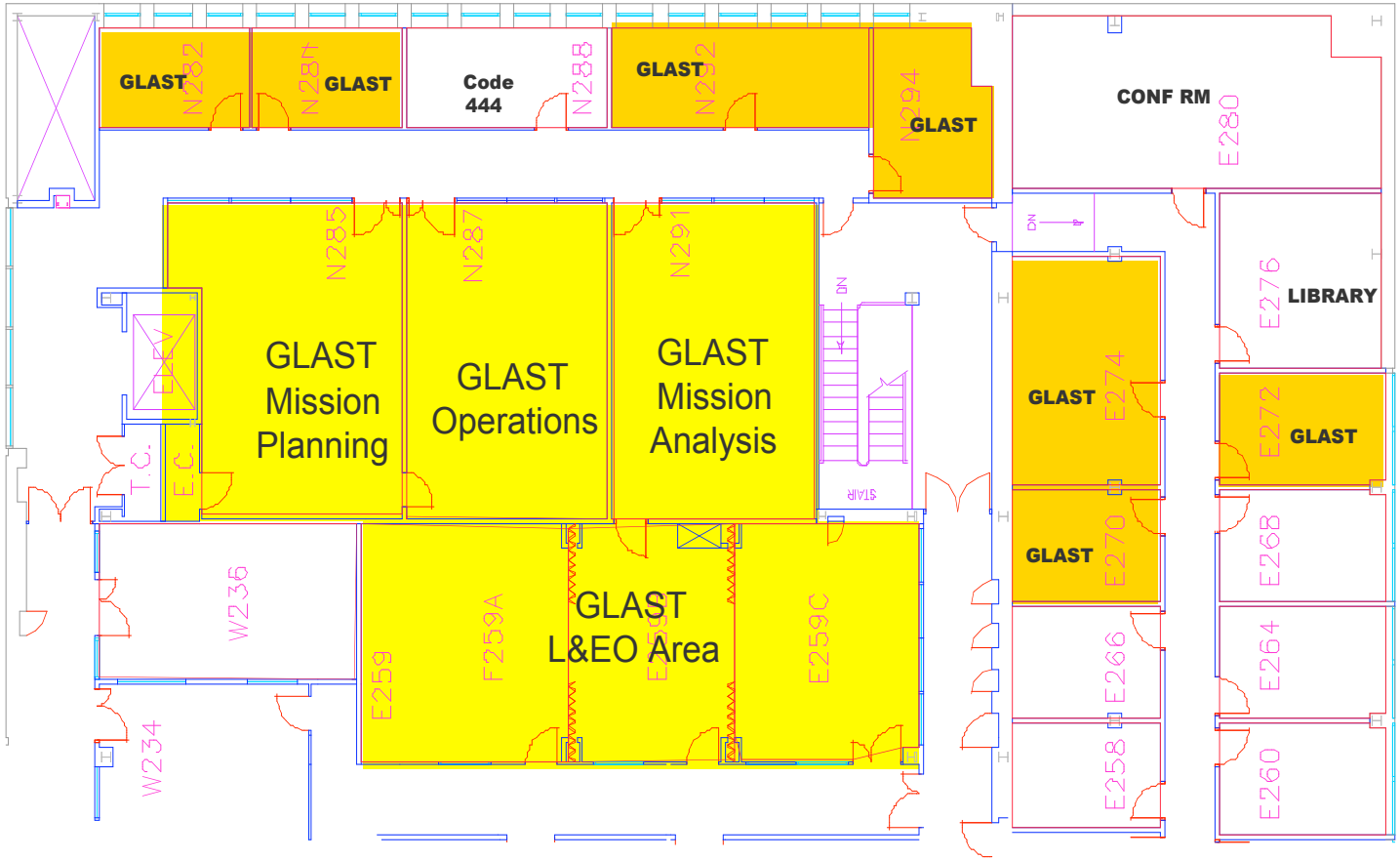


MOC Network


SPECTRUM
LEO (1...N)
OPEN1
MOCVMOC1
MOCVMOC2
ITOS Open Network Server MOC Webserver
VMOC/SERS Prime
VMOC/SERS Backup
SPECTRUM ASTRO (LEO Support Only)
100BaseT Switch
GLAST MOC OPEN 100Mbps Ethernet LAN SUBNET
DTAS Clients Email Documentation
DTAS Clients Email Documentation
DTAS Server
ADMIN1
ADMIN2
DTAS
Multi-subnet Firewall VPN Server
MOCITOS1
MOCITOS2
MOCITOS3
MOCBAP
ITOS PRIME TDRSS / GS R/T Telemetry & Command
ITOS PRIME TDRSS Alert R/T Telemetry & Command
ITOS OFFLINE Mission Monitoring Offline Telemetry MOC Fileserver MPS Backup STK Backup
Burst Alert Processor
100BaseT Switch
GLAST MOC CLOSED 100Mbps Ethernet LAN SUBNET
MPS Prime STK Prime ITOS Backup
LASER1
LASER2
Network Area

MOC Facility

Building 14
Second Floor North Corridor



GLAST operations space

Trade Studies

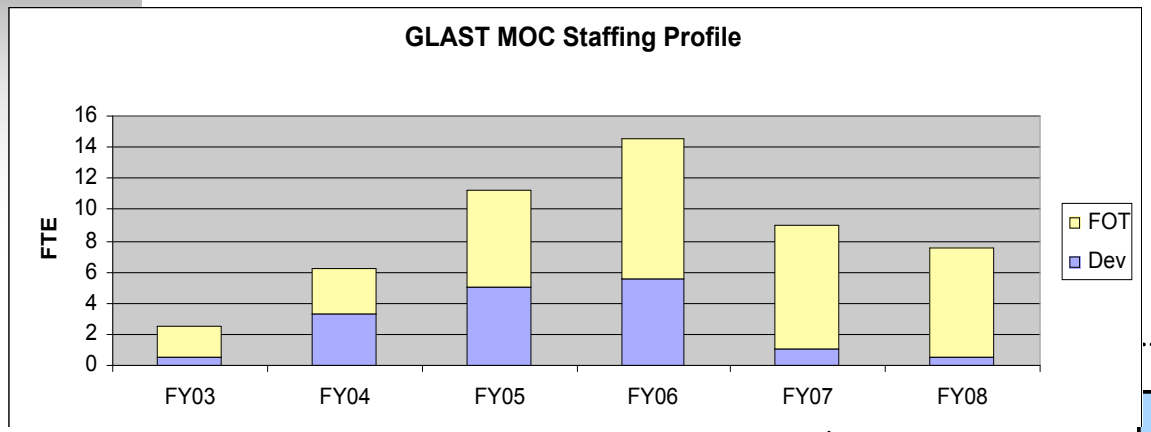
- ***GMSEC***
  - ***Technology evaluation (reliability and capability)***
    - *Attend demos and meetings*
    - *Documentation*
    - *Current users – follow TRMM development, assess feedback*
  - ***Target components***
    - *ITOS*
    - *Paging system*
    - *Trending system*
    - *Auxiliary tools such as event analyzer*
- ***PC/Linux vs. Sun/Solaris workstations***
  - ***speed benchmark***
  - ***evaluate platform change affect on software components***
- ***Attitude-dependent scheduling tools***
  - ***industry survey***
  - ***build our own***
- ***File exchange mechanism***
  - ***secure transfer of large files***
  - ***reuse Swift method or find another***

MOC Development Approach

Doug Spiegel

MOC Organization

- ***Goldbelt/Orca & Omitron teamed to provide MOC system, FOT***



GS&Ops Mgr
Mike Rackley
GSFC

MOC Lead
Dennis Small
GSFC

MOC Manager
Doug Spiegel
Omitron

Goldbelt-Orca/ Omitron

System/Operations Engineering
John Nagy
Jonathan DeGumbia
Omitron

Software Development
Marilyn Mix
Omitron

MOC Development Approach

- ***Based on Swift MOC model, leverage Swift system reuse and staff experience***
- ***Defined in MOC Development Plan***
- ***Develop Operations Concept, detailed MOC Requirements (level 4)***
  - ***Flow down from GSRD, establish traceability***
- ***Define architecture, interface protocols, develop system design***
  - ***Perform trade studies as needed to assess best fit of functionality, cost, ease of use, ease of maintenance***
- ***Package-based software development***
  - ***Integrate COTS/GOTS packages, configure & tailor where necessary for GLAST needs***
  - ***Augment with custom s/w to meet GLAST specific requirements***
- ***Incremental build & test approach***
  - ***Phasing of functionality driven by needs of ground system test program***

MOC Test Approach

- ***Multiple level testing follows incremental build approach***
  - *Unit level testing – Informal white box testing of individual or small number of integrated modules.*
  - *Integrated build testing – Black box, function-based testing of a group of integrated modules.*
  - *MOC element testing – Formal thread-based testing of complete MOC system for MOC requirements validation.*
  - *Integrated system testing (External elements, GRT, ETE) – Formal testing of partial and completely integrated ground system*
- ***Test program designed to validate key aspects of MOC element***
  - *Functionality*
  - *Performance*
  - *Security*
  - *Reliability*
  - *Interfaces*
  - *Recovery*
- ***Above aspects regression tested throughout integration of modules and builds***

MOC Test Approach (cont'd)

- ***Test cases developed to verify functionality and performance of each MOC component, proper generation of all required products***
- ***Test cases developed to verify system threads and end to end functionality for higher-level tests***
- ***Thread-based test procedures created to promote accountability and repeatability***
- ***Perform long duration test and negative testing to ensure system reliability, robustness***
- ***Testing relies on use of stubs, drivers, simulators (PSS, CTS, MTS, Hotbench), and test data as necessary***
- ***Discrepancy reports used to identify and track bugs to closure***
- ***Requirements verification and validation tracked with the requirements verification matrix***
- ***Complete test approach detailed in MOC Test Plan***

MOC Management Plan

- ***Project Management***
  - ***Participation in GOWG, GS/Ops staff meetings***
  - ***Develop & maintain detailed MOC development schedule including tasks for system engineering, software development, testing, ops preparation***
  - ***Provide monthly status report to GS/Ops Mgr & MOC Lead, identify issues/concerns and any risk items***
  - ***Track monthly cost/schedule against plan, report variances***
  - ***Track internal issues & action items to closure***

MOC Management Plan (cont.)

- ***Configuration Management***
  - ***Support Project- and Ground System-level CCBs as needed***
  - ***All MOC software, config files, Project DB, PROCs, pages, configmons, procedures controlled in CM repository using CVS tool***
  - ***Installation of MOC releases from CM repository, ability to revert to prior version if needed***
  - ***Key MOC documents controlled via Project or GS CCB (as appropriate)***
    - *MOC Level 4 Requirements to be controlled by GS CCB*
  - ***Documented in MOC CM Plan***

MOC Management Plan (cont.)

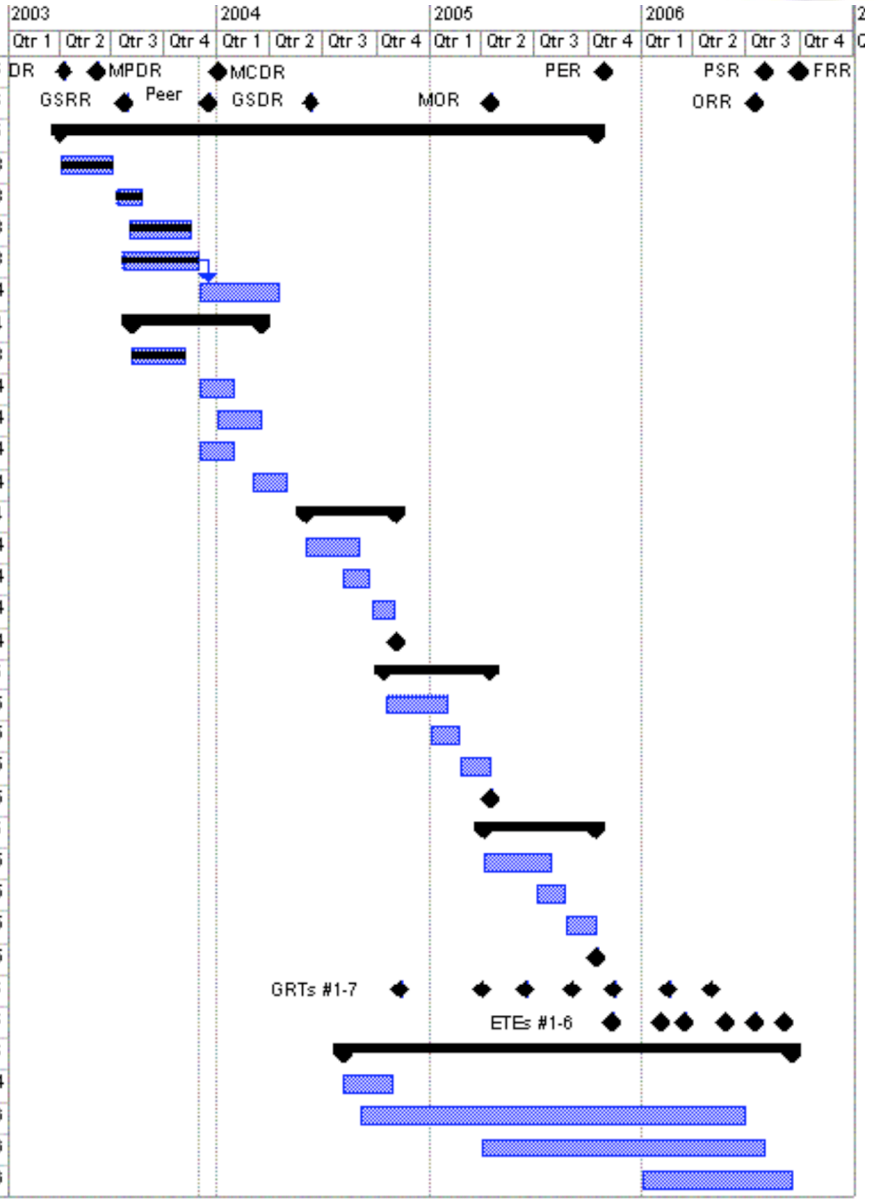
- ***Quality Assurance***
  - ***Walkthroughs held for all MOC requirements, component designs, code & unit tests, system test cases***
  - ***Peer Reviews held for MOC system design (prior to SDR) and operations plans (prior to MOR)***
  - ***Discrepancy Reports generated & maintained in online repository (e.g. SERS), tracked to closure***
    - *Online access allows Project complete insight into DRs*
    - *DR status, resolution plans coordinated with NASA MOC Lead*
  - ***All changes to controlled products reviewed; any requirements/scope or interface changes elevated to GS CCB for approval***
  - ***Regression testing performed to verify changes have not adversely affected existing functionality/performance***
  - ***Coordinate with QA Engineer (D. Harmon)***

MOC Documents

Document	Preliminary		Baseline		CCB	Doc No.	Author	Comments
	Milestone	Date	Milestone	Date				
Operations Concept Document	-	-	SRR+1 mo.	8/22/03	Project	433-OPS-001	J. Nagy	Rev A (Original baselined Mar'02)
Development Plan	SRR+1 mo.	8/22/03	SRR+3 mos.	10/20/03	Internal	492-MOC-001	D. Spiegel	
MOC Functional & Performance Requirements	SDR-6 mos.	11/15/03	SDR-2 mos.	3/31/04	GS	492-MOC-002	J. DeGumbia	
DB Format & Naming Convention	SRR+1 mo.	8/22/03	MCDR-1 mo.	2/15/04	GS	492-MOC-003	J. Nagy	
Proc Style Guide	SDR-5 mos.	12/1/03	SDR	5/31/04	Internal	492-MOC-004	J. DeGumbia	Procedures & STOL Procs
Design Spec	SDR-6 mos.	11/30/03	SDR	5/31/04	Internal	492-MOC-005	M. Mix	Revision post-SDR for RFAs
CM Plan	SDR-4 mos.	1/31/04	SDR	5/31/04	Internal	492-MOC-006	M. Mix	
MOC Test Plan	SDR-1 mo.	4/30/04	SDR+2 mos.	7/31/04	Internal	492-MOC-007		
Security Plan	SDR-3 mos.	2/15/04	SDR-1 mo.	4/30/04	GS	492-MOC-008	D. Aldridge	Revision post-SDR for RFAs
MOC-GSSC/IOCs ICD	SDR-6 mos.	11/5/03	SDR	5/15/04	GS	492-MOC-009	J. Nagy	Ops Data Products ICD
MOC-Backup GS ICD	SDR-2 mos.	3/15/04	SDR	5/15/04	GS	492-MOC-010		Backup Ground Station
Mission Ops Readiness Plan	MOR-6mos.	10/31/04	MOR+1	5/15/05	GS	492-MOC-011		
Training & Certification Plan	MOR+2 mos.	6/30/05	ORR-8 mos.	11/30/05	Internal	492-MOC-012		
Sustaining Engineering Plan	MOR+8mos.	12/15/05	ORR-2 mos.	5/31/06	Internal	492-MOC-013		
Flight Ops Manual	MOR-1 mo	3/15/05	ORR-1 mo.	6/15/06	Internal	492-MOC-014		
Transition Plan			L+8 mos.	5/30/07	GS	492-MOC-015		
Ops Agreements			ORR	7/15/06	GS	492-MOC-xxx		As Needed

MOC Schedule

ID	Task Name	Duration	Start	Finish
1	Project Milestones	910 days	Tue 4/8/03	Sat 9/30/06
9	Ground System Milestones	779 days	Tue 7/22/03	Fri 7/14/06
15	MOC Development	664 days	Tue 4/1/03	Fri 10/14/05
16	Ops Concept Document	65 days	Tue 4/1/03	Mon 6/30/03
17	MOC Development Plan	35 days	Mon 7/7/03	Fri 8/22/03
18	MOC Func. & Perf. Requirements	76 days	Fri 8/1/03	Fri 11/14/03
19	Preliminary System Design	99 days	Tue 7/15/03	Fri 11/28/03
20	Final System Design	99 days	Mon 12/1/03	Thu 4/15/04
21	ICDs	162 days	Mon 8/4/03	Tue 3/16/04
22	MOC - GSSC/IOCs ICD	68 days	Mon 8/4/03	Wed 11/5/03
23	FDF - MOC ICD	43 days	Mon 12/1/03	Wed 1/28/04
24	MOC - Backup Gmd Stn ICD	54 days	Thu 1/1/04	Tue 3/16/04
25	CM Plan	45 days	Mon 12/1/03	Fri 1/30/04
26	Test Plan	45 days	Mon 3/1/04	Fri 4/30/04
27	Release 1	110 days	Tue 6/1/04	Mon 11/1/04
28	Design / Code / Unit Test	66 days	Tue 6/1/04	Tue 8/31/04
29	Integration	35 days	Mon 8/2/04	Fri 9/17/04
30	System Test	31 days	Mon 9/20/04	Mon 11/1/04
31	R1 Delivery	1 day	Mon 11/1/04	Mon 11/1/04
32	Release 2	131 days	Fri 10/15/04	Fri 4/15/05
33	Design / Code / Unit Test	77 days	Fri 10/15/04	Mon 1/31/05
34	Integration	35 days	Mon 1/3/05	Fri 2/18/05
35	System Test	39 days	Mon 2/21/05	Thu 4/14/05
36	R2 Delivery	1 day	Fri 4/15/05	Fri 4/15/05
37	Release 3	140 days	Mon 4/4/05	Fri 10/14/05
38	Design / Code / Unit Test	85 days	Mon 4/4/05	Fri 7/29/05
39	Integration	35 days	Mon 7/4/05	Fri 8/19/05
40	System Test	40 days	Mon 8/22/05	Fri 10/14/05
41	R3 Delivery	1 day	Fri 10/14/05	Fri 10/14/05
42	Ground Readiness Tests	384 days	Wed 11/10/04	Mon 5/1/06
50	End-to-End Tests	211 days	Fri 11/11/05	Fri 9/1/06
57	Operations Prep	555 days	Mon 8/2/04	Fri 9/15/06
58	Mission Ops Readiness Plan	65 days	Mon 8/2/04	Fri 10/29/04
59	MOC & Ground System Testing	478 days	Wed 9/1/04	Fri 6/30/06
60	Ops Product Dev & Validation	348 days	Fri 4/1/05	Tue 8/1/06
61	Mission Simulations & Rehearsals	185 days	Mon 1/2/06	Fri 9/15/06



MOC Release Plan

- ***Release 1 (Nov '04) – GRT#1, 2***
  - *TLM & CMD Processing*
  - *Level 0 TLM Processing*
  - *Integrated Timeline and Command Load Generation*
- ***Release 2 (Apr '05) – GRT#3, 4***
  - *Alert Handling*
  - *Level 0 Product Distribution*
  - *Timeline Monitoring*
  - *Flight Dynamics*
- ***Release 3 (Oct '05) – GRT# 5***
  - *Attitude-dependant Contact Scheduling*
  - *System Automation*
  - *System Monitoring & Paging*
  - *Trending & Analysis*

Issues/Concerns

- ***Lack of long-term contract may impact MOC development and ops preparation***
  - ***Operating under interim GSA task, work continues without impact***
- ***Attitude-dependent scheduling complexity***
- ***GMSEC applicability, schedule, reliability, ease of integration***

Road Map to GSDR

- ***Complete & baseline MOC Level 4 Requirements***
- ***Complete & baseline MOC to Science & Instrument Centers ICD***
- ***Mature external interfaces***
- ***Conduct trade studies, resolve open design issues***
- ***Complete & baseline MOC Design Specification***
- ***Select & procure hardware***
- ***Setup Development Lab (at Omitron)***
- ***Complete Requirements traceability & allocation to software components***

Road Map to GSDR

External Dependencies

- ***Backup Ground Station Trade (Project)***
- ***LAT Data Rate Increase Trade (Project – Systems Group)***
- ***Survey Mode Rocking Profile Definition affect on TDRSS View Periods (Project – Systems Group)***
- ***DSN Interference Study (Project - Systems Group)***
- ***Simulator Capabilities/Delivery Schedule (Spectrum Astro)***
- ***Comm Network Architecture (Ground System Engineer)***
- ***Revised Launch Date Implications on MOC Schedule (Project)***
- ***"Hiatus Period" Implications on MOC Schedule/Activities (Project)***
- ***SNAS (SN Access System) Readiness for GLAST Ops (SN)***

Review Wrap Up

Dennis Small

GLAST MOC Peer Review Accomplishments

- ***Described plan and schedule for managing, implementing and testing of the GLAST Mission Operations Center***
- ***Presented the MOC requirements***
- ***Provided preliminary insight into future plans for achieving operations readiness***
- ***Identified open items, issues and external dependencies***

Board Caucus / RFA Review

- ***Review Panel Discussion/Feedback***
- ***RFA Review***
- ***Action Items***

Backup Slides

Mission Overview

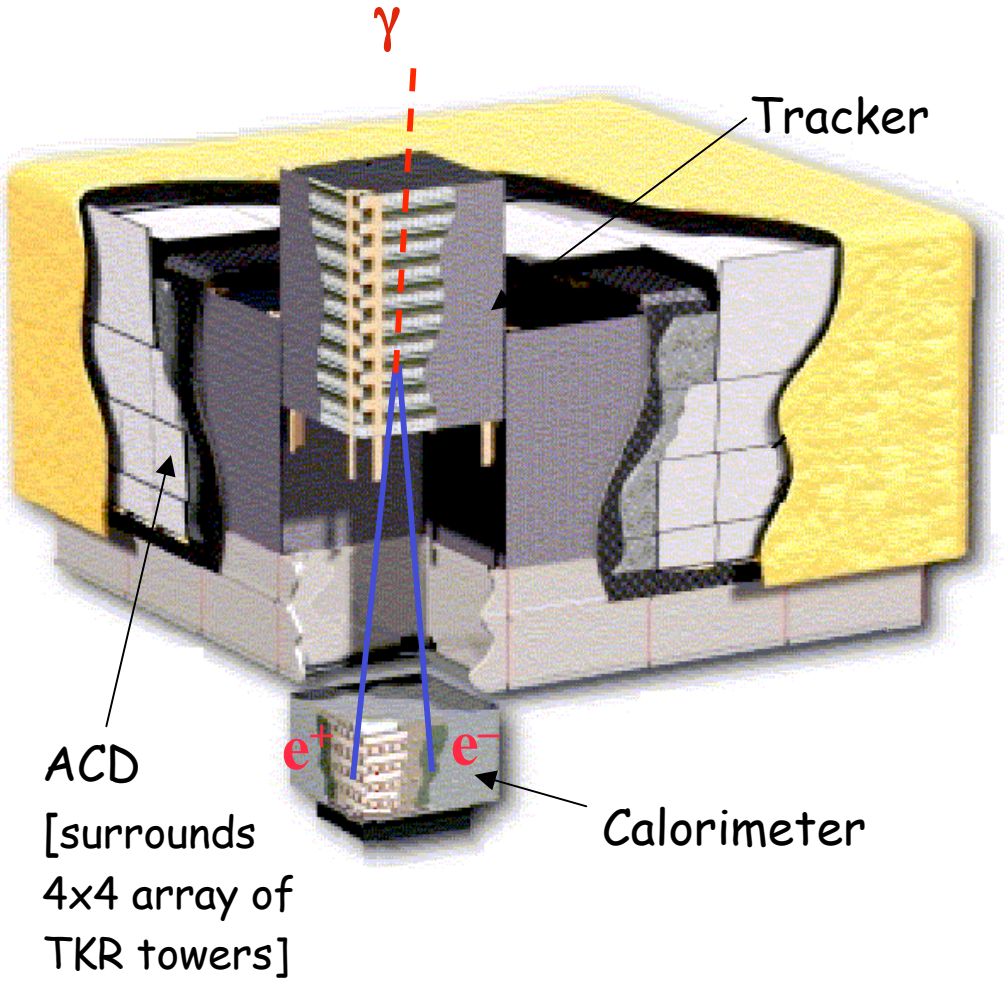
Ops Concept

Mission Overview: GLAST Science

- ***GLAST is a high-energy gamma-ray observatory for observing celestial sources in the energy band extending from 20 MeV to 300 GeV with complementary coverage between 10 keV and 25 MeV for gamma-ray bursts. GLAST will:***
  - *Identify/study **nature's high-energy particle accelerators** through observations of active galactic nuclei, pulsars, stellar-mass black holes, supernova remnants, gamma-ray Bursts, solar and stellar flares, and the diffuse galactic and extragalactic high-energy radiation.*
  - *Use these sources to **probe important physical parameters of the galaxy and the universe** such as: intensity of infrared radiation fields, magnetic fields strengths in cosmic particle accelerators, and diffuse gamma-ray fluxes from the Milky Way and nearby galaxies, and the diffuse extragalactic gamma-ray background radiation.*
  - *Use high-energy gamma-rays to **search for fundamentally new phenomena**: particle dark matter, quantum gravity, and evaporating black holes.*

Overview of LAT Instrument

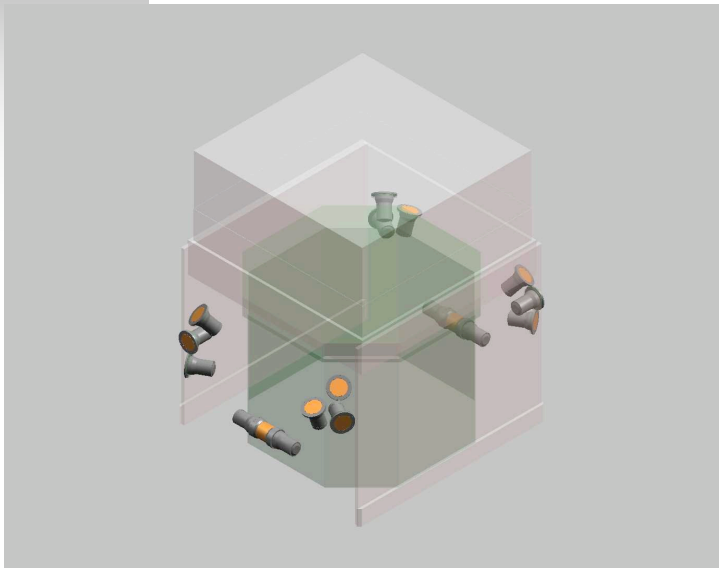
- *Precision Si-strip Tracker (TKR)*
  18 XY tracking planes. Single-sided silicon strip detectors (228 μm pitch) Measure the photon direction; gamma ID.
- *Hodoscopic CsI Calorimeter(CAL)*
  Array of 1536 CsI(Tl) crystals in 8 layers. Measure the photon energy; image the shower.
- *Segmented Anticoincidence Detector (ACD) 89 plastic scintillator tiles. Reject background of charged cosmic rays; segmentation removes self-veto effects at high energy.*
- *Electronics System Includes flexible, robust hardware trigger and software filters.*

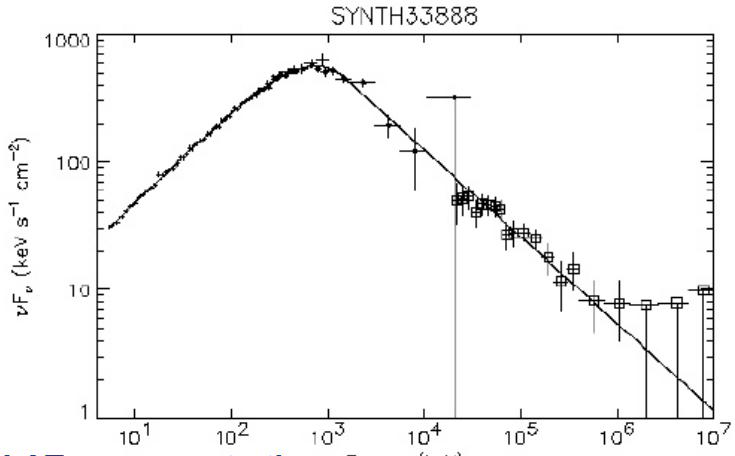


Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.

Overview of GBM Instrument

- ***Provides spectra for bursts from 10 keV to 30 MeV, connecting frontier LAT high-energy measurements with more familiar energy domain;***





Simulated GBM and LAT response to time-integrated flux from bright GRB 940217

Spectral model parameters from CGRO wide-band fit

1 NaI (14 º) and 1 BGO (30 º)

- ***Provides wide sky coverage (8 sr) -- enables autonomous repoint requests for exceptionally bright bursts that occur outside LAT FOV for high-energy afterglow studies (an important question from EGRET);***
- ***Provides burst alerts to the ground.***

Mission Operations Backup Slides

SSR Playback via Stored Command

- ***Scenario #1: All SSR commands are in the ATS load. No ground commanding during unattended passes.***
  - *An Autonomous Repoint attitude places the Ku-band antenna in a view which obscures the pre-planned TDRSS contact.*
  - *Transmitter On and Start SSR playback commands are in the ATS and take place. Data is dumped but TDRSS doesn't get it. The SSR pointers advance accordingly.*
  - *MOC/FOT paged of the missed event. Need to travel to MOC during off shift to support.*
  - *MOC/FOT has to check schedule and plan for a new TDRSS support to redump the missed data. A manual process and may occur frequently depending on how many ARs occur each week and if they affect the pre-planned TDRSS contacts.*
  - *Prior the support the MOC/FOT must determine which data was missed. (Calculate the SSR pointer positions for the missed data.)*
  - *During the support the data must be played back by ground command and then the pointers must be reset to the original position before the re-dump. There is a greater chance for a loss of data with commanding the read/write pointers in the SSR.*
  - *The missed data may be overwritten depending on how quickly the FOT can initiate the redump of the missed data.*

SSR Playback via Ground Command

- ***Scenario #2: SSR playback commands are sent during the ground contact from the automated MOC procedure.***
  - *An Autonomous Repoint attitude places the Ku-band antenna in a view which obscures the pre-planned TDRSS contact.*
  - *Transmitter On and housekeeping telemetry sent but not received by TDRSS.*
  - *MOC/FOT automation detects lack of telemetry and pages FOT of the missed event. FOT can check the planned pass schedule and evaluate if further action is necessary. Probably just a wait and see approach.*
  - *Data was not dumped because the MOC didn't command it. The SSR pointers did not advance accordingly. SSR just keeps accumulating data in the que.*
  - *The next planned event is nominal and as much data as possible is downlinked during the allotted time. It may take 2 or 3 planned contacts to completely downlink all the missed contact data (and new telemetry) depending on the length of each contact and their separation.*
  - *Only extreme situations or frequent autonomous repoints would require MOC/FOT intervention during unattended shifts.*
  - *The recorder is less likely to overwrite because the newest data is the part that is retained during each downlink.*

Missions currently with automated commanding

- ***FAST – automation for over 3 years***
  - *6 months automation at GSFC before transition of operations to Univ. CA at Berkley*
  - *ATS loads, onboard events file dump, SSR dumps and re-dumps, sun nadir file loading*
- ***IMAGE – automation for over 3 years***
  - *1 staffed pass per week*
  - *Daily SSR dumps from automated ground command*
  - *Data gap detection and re-dump from ground automatically*
  - *SSR management*
  - *Very good data capture percentages with existing automation*
- ***MAP – automation for over 2 years***
  - *Daily SSR dumps from automated ground command*
  - *Data gap detection and re-dump from ground automatically*
  - *Excellent data capture percentages with existing automation*
- ***RXTE and ACE – some automation for several years***
  - *Currently have the automation necessary to do most routine activities automated*
- ***CGRO – some automation before de-orbit***